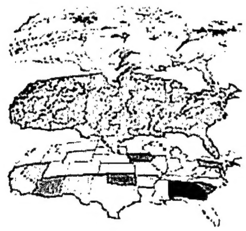

GAP ANALYSIS

BULLETIN

No. 10

A Geographic Approach to Planning for Biological Diversity

U.S. Department of the Interior
U.S. Geological Service

DISTRIBUTION STATEMENT A
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2001

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NATIONAL NOTES

An Integrated GAP and NBII

The National Biological Information Infrastructure (NBII) <http://www.nbii.gov> is a broad, collaborative program to provide increased access to data and information on the nation's biological resources. The NBII links many different biological databases, information products, and analytical tools that have been developed and maintained by NBII partners and contributors in government agencies, academic institutions, nongovernment organizations, and private industry. NBII partners and collaborators also work on new standards, tools, and technologies that make it easier to find, integrate, and apply biological resources information. Resource managers, scientists, educators, and the general public use the NBII to answer a wide range of questions related to the management, use, or conservation of this nation's biological resources.

One of the key components of the NBII is a system of nodes that is being developed to ensure inclusion and participation from all sectors of society. The NBII nodes are of three types: regional, thematic, and infrastructure.

> *Regional nodes* have a geographic orientation and represent a regional approach to local data issues, data collectors, and owners.
>
> *Thematic nodes* focus on a particular biological issue (for example, amphibian decline and deformity), providing the support and infrastructure to help address these issues that usually transcend geographic regions.
>
> *Infrastructure nodes* are devoted to development or adoption of standards, tool suites, and common protocols. These facilitate interoperability among nodes and between the NBII and other national and international systems.

As part of the overall NBII effort, GAP investigators are helping many organizations apply GAP data to their own activities. Hundreds of applications of GAP information—both data and analyses—have been made nationwide, ranging from forest management, conservation planning, and scientific research endeavors to business and industry applications. For a sample of GAP applications see www.gap.uidaho.edu/applications/applications.htm.

In addition to GAP, some other programs of the NBII include:

ITIS and TRED

The NBII is working with several partner agencies and organizations to help provide access to these two important sources of biological taxonomic information. The Integrated Taxonomic Information System (ITIS; www.itis.usda.gov) is the first comprehensive, standardized reference for the scientific names—as well as synonyms and common names—of all the plants and animals of North America and the surrounding oceans. The Taxonomic Resources and Expertise Directory (TRED; www.nbii.gov/datainfo/syscollect/tred/) is an online directory of taxonomic specialists with expertise on the biological diversity of North America (north of Mexico) and adjacent oceans.

LUHNA

The Land Use History of North America program (LUHNA http://biology.usgs.gov/luhna/) seeks to understand the relationships between human land use and land cover change and works to assess future implications of these interactions. LUHNA products and research results are widely available to Internet users through the NBII.

Vegetation Mapping Program

The U.S. Geological Survey is cooperating with the National Park Service to produce detailed, computerized maps of the vegetation of 250 National Park units across the United States (http://biology.usgs.gov/npsveg/). Through this program a wide variety of data and synthesized information on the vegetation resources of our National Parks are being made available to Internet users through the NBII.

The nodes and programs discussed above illustrate just some of the NBII's growing capability to foster the dissemination of GAP and similar products and concepts. Some readers may recall past discussions within the GAP community about GAP's diffusion to, and adoption by, major sectors of society as a technical innovation (for example, see Forester et al. 1996). Now that many of the first generation GAP state projects have been completed, and large amounts of biological, land management, and analytical spatial data are available, the NBII is providing the vehicle for wide dissemination of the information along with a great deal of other complimentary biological information, such as taxonomic and historical information. Those early discussions could not have anticipated the magnitude of improvements in information technology, nor the related development of a broad infrastructure for the nation's biological information. Today, the integration of GAP data with the NBII significantly improves both the rate and extent of GAP product dissemination and adoption.

To review briefly, the diffusion of innovations is the process by which an innovation is communicated through certain channels over time among the members of a social system. It is a special kind of communication because the messages have to do with new ideas. The four main elements of the diffusion of innovations are:

- The innovation
- Communication about the innovation
- The time or rate of diffusion
- The social system that adopts or rejects the innovation (Rogers 1983)

Two of these elements—communication about the innovation and the time or rate of diffusion—become positively affected under the broad NBII umbrella of increased access to data and information on the nation's biological resources. The NBII is facilitating communication about GAP products among a wider, more diverse audience than the proximate community of those producing GAP information. And the NBII is speeding up the rate of diffusion of GAP products through its larger infrastructure.

The NBII is also vital to the interface with the fourth element, the social system that adopts or rejects the innovation. In this regard, a better understanding of this element is beginning to emerge. It is clear, for example, that there is not just one social system but a number of quite different social systems that collectively make up the group of GAP users.

For example, in their article on barriers to the use of GAP data by local and regional land use planners in New Mexico, Russ Winn and Diane-Michele Prindeville (page 32) show that in this case the factors limiting the adoption of GAP is less one of access, it is actually about social values. The social values governing county land use planning in New Mexico are heavily weighted to economic development. This is in contrast to a rapidly developing urban county with different social values that recently adopted GAP spatial data and analyses as a direct part of their detailed conservation planning process (see "A Biodiversity Plan for Pierce County, Washington" at www.co.pierce.wa.us/xml/services/home/property/pals/pdf/gap.pdf). In her article on conservation planning in Tennessee (page 41), Marty Marina discusses the impact GAP has had in developing a capability for conservation planning in that state, and the time and effort that it took to achieve adoption. Steve Williams, Casson Stallings, JohnAnn Shearer, and Alexa McKerrow describe in their article (page 29) an important tool for disseminating GAP information within the U.S. Fish and Wildlife Service. They point the way along an avenue of an integrated GAP and NBII.

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Gap Analysis of the Flora of Wyoming

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Beginning with the establishment of Yellowstone National Park in 1872, nearly 10% of the state of Wyoming has been set aside as GAP status 1 or 2 lands. Most of these areas were initially protected for their scenic, historic, or recreational values rather than for conserving biodiversity, and they tend to be concentrated in the Greater Yellowstone Ecosystem and other high-elevation areas (Figure 1). The Wyoming GAP Project used modeled distributions of 445 terrestrial vertebrate species and 42 land cover types to assess the effectiveness of status 1 and 2 lands in conserving the state's biodiversity. Not surprisingly, the gap analysis revealed high levels of protection for species and cover types found in montane and alpine habitats and minimal protection for elements in low-elevation areas of eastern and southern Wyoming (Merrill et al. 1996).

Vascular plant species were not included in the initial Wyoming Gap Analysis, nor have they traditionally been assessed in other states. However, state or regional floras may be more useful probes of biodiversity protection than vertebrates or land cover types. Because of their high levels of species richness, endemism, and habitat specialization, plants are a useful proxy for total biodiversity. Being sessile organisms, plants are also easier to map and positively locate in different GAP land management areas. Finally, large data sets of point locations are available for plants from herbarium records and floristic checklists.

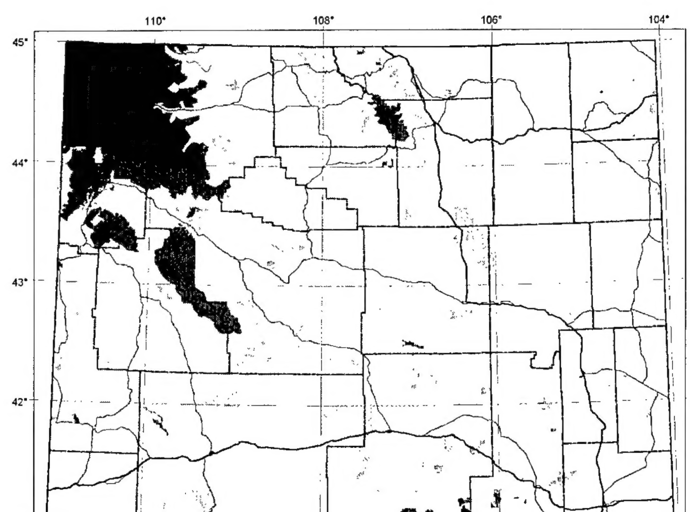

Figure 1. Revised GAP land status map of Wyoming with Research Natural Areas, Nature Conservancy preserves and easements, and BLM Areas of Critical Environmental Concern established since publication of the original state land status map in Merrill et al. (1996).

With funding from National GAP, we used dot distribution and modeled habitat maps to conduct the first gap analysis of the flora of Wyoming. Location points were derived for 2,770 of the state's 2,800 vascular plant taxa (Dorn 2001) from the digital specimen database of the Rocky Mountain Herbarium (www.uwyo.edu/botany/herb.htm), the state natural heritage program (www.uwyo.edu/wyndd), and available checklists for special management areas (Fertig 2000, 2001; Fertig and Oblad 2000; Heidel and Fertig 2001; Shaw 1992; Whipple 2000, 2001). All duplicate records (representing the same collector or locality) were eliminated, leaving a final data set of 208,659 points. These points were overlaid on the state GAP land status coverage to determine the number and percentage of points of each species in the four land status categories. The same values were calculated with the state's flora subdivided by major biome types (alpine, eastern deciduous forest, Great Plains grasslands, Rocky Mountain forest, intermountain desert steppe, and wetlands), and for non-native and rare species. The land status coverage was modified from Merrill et al. (1996) to include new Research Natural Areas, Nature Conservancy (TNC) preserves and easements, and BLM Areas of Critical Environmental Concern (ACECs) established since 1996 (Figure 1).

Potential distribution maps were created for 100 plant species based on correlations between selected environmental variables and known plant locations in Wyoming and adjacent states (Fertig 1999). Digital versions of these models were overlaid with the revised land status layer to derive the percentage of area in Wyoming falling in each of the four GAP categories.

Based on our revised land status coverage, the total area of Wyoming under GAP status 1 or 2 management is 26,695 km^2 (10.55% of the state). These lands contain at least one population for 2,261 of the state's 2,770 plant species that we examined (81.62%) (Table 1). 1,263 of these taxa (45.6%) have at least five or more populations in status 1 or 2 lands, and 1,557 taxa (56.21%) have over 10% of their known populations under protection. Alpine species are the best represented, with 158 of 163 taxa (96.93%) being found at least once in GAP 1 or 2 areas and 107 taxa (65.64%) having at least 50% of their populations protected. Wetland and Rocky Mountain forest plants are also relatively well protected, with 87.86–90.54% of their species present at least once in status 1 or 2 lands. By contrast, plants of the eastern deciduous forest, intermountain desert steppe, and Great Plains grasslands have only 72.52–77.68% of their species minimally represented in GAP 1 or 2 areas. Although only 40 of 52 eastern deciduous forest species occur in protected sites, 37 of these (71.16%) have at least 10% of their populations in preserves. Of 261 intermountain desert steppe taxa in protected areas, only 90 (26.79%) have at least 10% of their populations represented. Plants of the Great Plains have the lowest levels of protection, with only 293 of 404 species present on protected lands and less than 15% of the flora having over 10% of their populations preserved (Table 1).

The state natural heritage program recognizes 522 plant taxa of "special concern" (Fertig and Beauvais 1999). Of these species, 196 (37.55%) currently receive no protection in GAP 1 or 2 areas of Wyoming. The percentage of unprotected rare species in Wyoming is just over twice as high as the percentage of unprotected taxa in the state flora as a whole. Only 230 rare plant species (44.06%) have at least 25% of their known occurrences in preserves (Table 1).

Table 1. Number and percent of vascular plant species with 0%, >0-10%, >10-25%, >25-50%, and >50% of their populations in GAP status 1 or 2 lands in Wyoming.

	0% of pops. in GAP 1 & 2	>0 – 10% of pops. in GAP 1 & 2	> 10 – 25% of pops. in GAP 1 & 2	> 25 – 50% of pops. in GAP 1 & 2	> 50 % of pops. in GAP 1 & 2	
Flora	No. and % of taxa	No. and % of taxa	No. and % of taxa	No. and % of taxa	No. and % of taxa	Total
Total Wyoming	509 (18.38%)	704 (25.42%)	708 (25.56%)	491 (17.73%)	358 (12.92%)	2770
Alpine	5 (3.07%)	0 (0%)	12 (7.36%)	39 (23.93%)	107 (65.64%)	163
Eastern Deciduous Forest	12 (23.08%)	3 (5.77%)	26 (50%)	8 (15.39%)	3 (5.77%)	52
Great Plains Grasslands	111 (27.48%)	233 (57.67%)	51 (12.62%)	6 (1.49%)	3 (0.74%)	404
Intermountain Desert Steppe	75 (22.32%)	171 (50.89%)	60 (17.86%)	23 (6.85%)	7 (2.08%)	336
Rocky Mountain Forest	88 (9.46%)	129 (13.87%)	331 (35.59%)	263 (28.28%)	119 (12.8%)	930
Wetland	63 (12.14%)	80 (15.41%)	157 (30.25%)	122 (23.51%)	97 (18.69%)	519
Non-native	155 (42.35%)	88 (24.04%)	71 (19.4%)	30 (8.2%)	22 (6.01%)	366
Plants of Special Concern (Fertig & Beauvais 1999)	196 (37.55)	19 (3.64%)	77 (14.75%)	97 (18.58%)	133 (25.48%)	522

Conversely, 366 non-native plant taxa have been documented for the flora of Wyoming, of which 211 (57.45%) occur at least once in status 1 or 2 lands. Fifty-two of these species (14.21%) have more than 25% of their known occurrences in highly protected areas.

For 100 modeled species we found little overall difference in the average percentage of a species' predicted area within status 1 or 2 lands and the average percentage of known populations of the same species in the protected areas (21.03% vs. 20.97%, respectively, Table 2). Individual models and dot distribution maps could differ significantly, however, with modeled ranges typically overpredicting protection for many alpine, Rocky Mountain forest, and wetland species, and point maps doing the same for eastern deciduous forest taxa and rare plants.

Models are a useful tool for identifying new areas of potential habitat for species of high management interest (Fertig 1999) but should not substitute for ground-based confirmation of presence in protected areas. Point-based coverages have limitations too in that they may reflect unequal or biased sampling (with private lands being especially underrepresented). Use of species lists may also suffer from unequal sampling intensity and possible misidentifications. In Wyoming, TNC easements, state Wildlife Habitat Management Areas, ACECs, and national forest wilderness and special interest areas outside the Greater Yellowstone area are especially undersampled at present and may provide better levels of protection than currently detected. As with all gap analyses, care must be taken in presuming that presence in a protected area equates with adequate management, minimum viable population size, and occurrence of necessary ecological conditions for any given species.

Table 2. Comparison of protection status using modeled distribution vs. point location maps for selected plant species in Wyoming. * indicates a species of special concern. Flora acronyms are: ALP (alpine), EDF (eastern deciduous forest), GRS (Great Plains grasslands), IDS (intermountain desert steppe), RMF (Rocky Mountain Forest), and WET (wetlands).

Species	**Flora**	**Modeled Distribution**		**Point Locations**	**% modeled - % points**
		Area in GAP 1 or 2 lands (km^2)	% model in GAP 1 or 2 lands	% points in GAP 1 or 2 lands	
Aconitum columbianum	RMF	13,173	34.07	22.83	11.24
Ambrosia trifida	GRS	262	0.98	4.00	-3.02
Artemisia pedatifida	IDS	1,481	1.85	1.33	0.52
Artemisia tripartita var. *rupicola*	RMF	1,278	7.48	6.77	0.71
Astragalus geyeri	IDS	756	2.15	4.88	-2.73
Carex blanda	EDF	12	1.57	23.07	-21.50
Carex lenticularis var. *pallida*	WET	532	35.74	31.58	4.16
Ceanothus velutinus	RMF	7,938	21.69	22.84	-1.15
**Cleome multicaulis*	WET	1	67.66	50.00	17.66
Cryptantha cinerea var. *jamesii*	GRS	422	0.88	1.16	-0.28
**Cymopterus evertii*	IDS	1,305	13.18	41.67	-28.49
Draba aurea	GRS	13,220	47.46	45.38	2.08
**Festuca hallii*	RMF	441	16.77	36.36	-19.59
Noccaea montana	RMF	7,083	35.48	16.00	19.48
Panicum virgatum	GRS	187	0.95	5.26	-4.31
**Parrya nudicaulis*	ALP	1,012	72.29	100.00	-27.71
Penstemon saxosorum	RMF	4,393	37.21	0.00	37.21
Phalaris arundinacea	WET	173	5.99	11.86	-5.87
Thelesperma marginatum	RMF	341	2.88	0.00	2.88
Trifolium nanum	ALP	1,103	61.64	44.00	17.64
Average of 100 modeled taxa		**2,930**	**21.01**	**20.97**	**0.05**
Standard deviation			**22.49**	**21.76**	

The use of vascular plants to identify patterns in overall biodiversity protection corroborates the findings of other gap analyses using terrestrial vertebrates and land cover types (Merrill et al. 1996; Scott et al. 2001). We find that alpine and montane upland and wetland species have much higher representation in GAP status 1 or 2 lands in Wyoming than taxa from the Great Plains, eastern deciduous forest, and intermountain desert steppe. Rare species are also twice as likely to be absent from the existing protected areas network as wide-ranging species. Floras confer additional advantages for gap analysis because their high species richness, mix of habitat generalist and specialist taxa, and large pool of location information contribute to a more robust data set than vertebrate faunas or coarse vegetation types. By determining the protection status of individual plant species, conservationists have a precise tool for identifying and prioritizing biome types, geographic areas, and suites of species that are underrepresented in the protected areas network.

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Managing Biodiversity in Oklahoma: A Case for Private Land Conservation

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It is widely recognized that biodiversity cannot be conserved solely through a strategy of establishing reserves, which are mostly on public lands. Reserves are too few to support all elements of biodiversity, many are too small to sustain genetic or species diversity, and they are often geographically separated, making it difficult to generate and maintain political support (Vickerman 1998). Private lands, which constitute nearly 50% of the U.S., support significant elements of biodiversity and are increasingly a focus of state biodiversity conservation programs (Schlickeisen and Musgrave 1996). Oklahoma, like most eastern and mid-continent states, is composed almost entirely of privately owned land. The Oklahoma Gap Analysis Project (OK-GAP) found that private lands comprise 94.5% of Oklahoma. Nearly all of these lands are managed for agricultural (e.g., rangeland, cropland, or pastureland) or forestry uses. As such, there is limited focus on managing these lands for biodiversity conservation, although there are many opportunities for doing so (Murray 1996).

Most of the stewardship lands in Oklahoma are owned and managed by 13 federal and state agencies. Federal and state agencies with the largest holdings of stewardship lands are the U.S. Army Corps of Engineers (1.2%), U.S. Fish and Wildlife Service (0.9%), and Oklahoma Department of Wildlife Conservation (0.7%). Less than 2% (3,347 sq km) of the total land area of Oklahoma (181,124 sq km) is GAP stewardship status 1 and 2 lands, and many of these occur in the eastern half of Oklahoma. Status 3 lands comprise nearly 4% (6,540 sq km) of the state's land area, and these lands are

scattered throughout the state. Although many of these stewardship lands occur in areas of high biological diversity, none of them are very large, and few are contiguous. The average size of the 72 status 1 and 2 land management units is 46 sq km (range 0.31-522.62 sq km).

To illustrate the fragmented character of stewardship lands in relation to biologically diverse areas and significant features in Oklahoma, we overlaid status 1 and 2 lands on the hexagon map of mammal species diversity (Figure 1). In general, vertebrate species diversity increases from west to east in Oklahoma; however, mammal diversity tends to be more clumped. Areas of high mammal species richness tend to be associated with significant natural features in Oklahoma including the Ozark Plateau in the northeast, Ouachita Mountains in the southeast, Wichita Mountains in southwest, Gypsum Hills in the northwest, and Black Mesa at the tip of the panhandle. In addition to diverse mammal assemblages, each of these areas supports a diversity of natural vegetation types (Aldrich et al. 1997). It is apparent from the overlay (Figure 1) that although status 1 and 2 lands do coincide with some areas of high species richness for mammals, these lands are small and widely separated from one another, thus providing little opportunity for development of a reserve network.

It is clear that biodiversity conservation in Oklahoma will depend on working cooperatively with private landowners. Directed educational efforts will be needed to inform landowners and the public in general about the value of Oklahoma's rich natural heritage and what can be done to enhance it. Fortunately, the Oklahoma biodiversity plan (Murray 1996) identifies a strategy for educating Oklahomans about biodiversity conservation. In addition to education, there will need to be a legal and policy framework in place to support biodiversity conservation efforts. Some states (e.g., Oregon, California, Kentucky, Michigan, New York) have developed formal biodiversity policies (Schlickeisen and Musgrave 1996) that are guiding education efforts and providing incentives. With the completion of OK-GAP, Oklahoma is now poised to move forward in implementing a strategy for conserving biodiversity that focuses on private land owners as well as public land managers.

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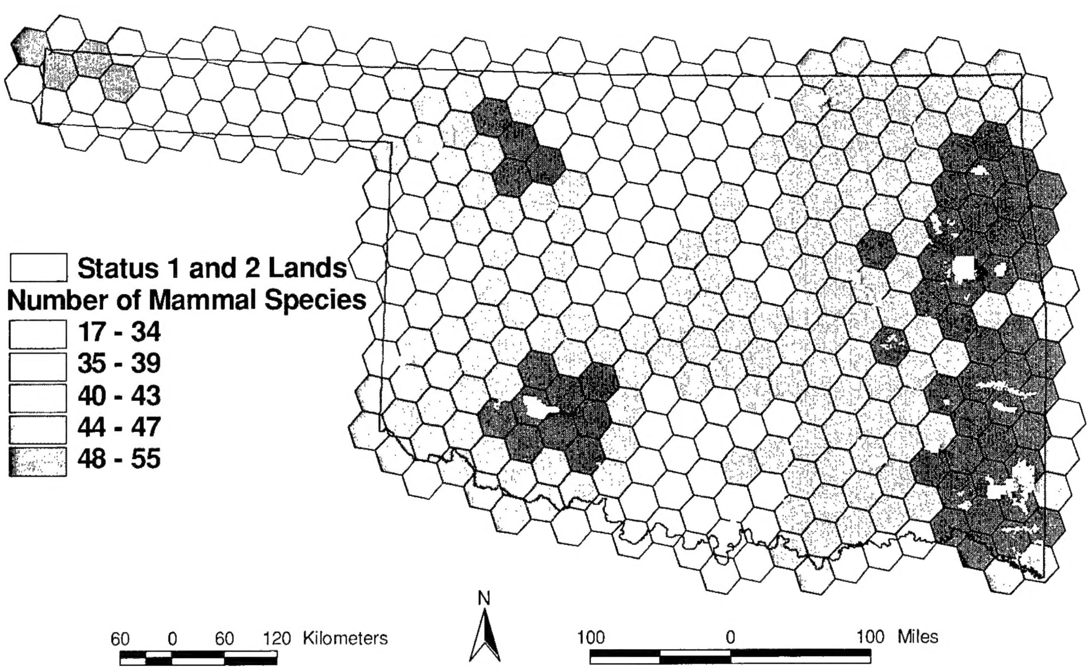

Figure 1. Distribution of status 1 and 2 stewardship lands in relation to mammal species richness in Oklahoma.

The Gap Analysis Program on the Assessment of Nature Reserves of Mexico

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Introduction

Mexico is considered one of the most biodiverse countries in the world (Mittermeier 1988, Dinerstein et al. 1995, Instituto Nacional Indigenista 2001). Its territory of 1,953,162 km^2, with 11,208 km of coasts, is nearly equally distributed above and below the Tropic of Cancer. The insular territory of Mexico comprises 371 islands, coral reefs, and kelp beds (CONABIO 1998).

There are 127 nature reserves, covering 7.8% of Mexico's continental land area, within the national system of natural protected areas (SINAP; CONABIO 2001). The distribution of these reserves does not represent the biological, geophysical, or political divisions of the country. For example, the states of Tamaulipas, Aguascalientes, and Guanajuato lack any federal nature reserves. As in the U.S., individual state governments can also establish and manage parks or protected areas.

The Mexican state of Nuevo Leon, located in the northeastern portion of the country, currently has 23 state and three federal nature reserves that cover approximately 4.4% of its land area. The state of Tamaulipas, located east of Nuevo Leon, has no federal nature reserves but five state nature reserves covering approximately 2.8% of its land area.

The National Commission for Knowledge and Use of Biodiversity (CONABIO) identified conservation priorities for Mexico based on the biological characteristics of specific areas, recognizing 151 terrestrial and 70 marine regions throughout the country as priority areas for the protection of biodiversity (Arriaga et al. 2000). Twelve areas were proposed for Nuevo Leon. If established as reserves, the proportion of protected lands in that state would exceed 23%. CONABIO proposed 13 terrestrial and 5 marine reserves for Tamaulipas; if established, these new reserves would increase the proportion of terrestrial protected areas in that state to 23.7%.

Efforts to identify gaps in networks of nature reserves have been conducted using biological features (Scott et al. 1993) as well as enduring physical features (Hunter et al. 1988). Cantú et al. (2001a, 2001b, 2001c) used both approaches in an assessment of the adequacy of existing and proposed nature reserves to capture the variation in elevation, climate, physiography, floristic divisions, potential vegetation types, mammalian, reptilian, and amphibian faunal provinces, and land use. This assessment was conducted for the entire country of Mexico and in more detail for the states of Nuevo Leon and Tamaulipas. This article briefly reports the results of that assessment.

This assessment was done using the best available data for Mexico as a whole and Nuevo Leon and Tamaulipas in particular. These data are both spatially and thematically coarse, and the effort is intended to show how the Gap Analysis method of identifying gaps in biodiversity conservation lands may be applied in Mexico as well as individual states of Mexico if spatial data of actual dominant vegetation types and each vertebrate species were available. The analyses presented here show the general level to which categories of elevation, physiography, potential vegetation types, faunal realms, and land use are represented in existing and proposed natural reserves and only indirectly provide a sense of the degree to which the overall biodiversity of Mexico, Nuevo Leon, and Tamaulipas is represented in these areas.

Methods

Digital maps of the proposed reserves (Cantú et al. 2002a, 2002b,2002c) and elevation (INEGI et al. 1990), climate types (García and CONABIO 1998), soil types (INEGI et al. 1991), physiography (Cervantes-Zamora et al. 1990), floristic divisions (Rzedowski and Reyna-Trujillo 1990), potential vegetation types (Rzedowski 1990), mammalian, reptilian, and amphibian faunal provinces (Ramírez-Pulido and Castro-Campillo 1990, Casas Andreu and Reyna Trujillo 1990), and land use and land cover for 1973 and 1996 (INE and INEGI 1996, CONABIO 1999), as well the boundaries of proposed terrestrial reserves, were obtained from the CONABIO web site (www.conabio.gob.mx). The boundaries of the existing nature reserves were provided by the National Commission of Natural Protected Areas (SEMARNAT) and the state governments of Nuevo Leon and Tamaulipas.

All of the data sets were combined and analyzed using ARC/INFO version 8.02 and ArcView version 3.2 software. Differences in map scales and map projections for the various data sets caused the area estimates calculated for the different categories to vary. However, considering the broad scale of the analysis, we did not consider these differences to be meaningful.

For the purposes of this analysis it was assumed that any resource category with less than 12% of its area in protected areas was underrepresented. We chose 12% because that percentage has been suggested in the past as a conservation target for entire nations (Bruntland 1987, IUCN 1992). However, it has not been proposed as a conservation target for particular resource categories, and we do not suggest that this figure has any established scientific validity.

Results and Discussion

We found that the 127 existing federal reserves, when combined with the additions proposed by CONABIO, would place 29% of Mexico's land area in nature reserves. The existing reserves adequately protected (i.e., > 12%) only those lands with elevations > 3000 m (which represent < 1% of the country). Adding the reserves proposed by CONABIO results in all elevation zones, climatic divisions, and physiographic provinces having at least 12% of their lands in protected areas. With the existing set of reserves, the analysis of 1973 land cover data indicated that nine of the 23 potential vegetation types exceed the 12% standard in the current nature reserves. Under the "existing and proposed" reserve scenario, all 23 of the potential vegetation types would be protected. Under the existing nature reserves scenario, oak forest, pine forest, cloud forest, chaparral, savanna, three types of tropical forest and five types of xeric scrubs are underrepresented. All categories exceed the 12% threshold in the current and proposed nature reserves, and 14 categories have 30% or more of their area in current and proposed nature reserves.

Despite the increased protection of biological and geophysical features provided by the proposed CONABIO reserves, gaps remained when the analysis was conducted at the state level. For Tamaulipas, we found that most of the existing protected sites occur in areas with elevations > 1,000 m. These are in temperate climates and are dominated by pine forest, oak forest, and cloud forest cover types. The state's dominant physiographic region—low-elevation coastal plain with tropical and arid climate types and xeric scrub vegetation—is disproportionately underrepresented in the current reserve system. If the new protected areas were established, the largest gap would be in the low-elevation, level, coastal lands. For example, for the five xeric scrub types that cover 35% of Tamaulipas, less than 1% of their area is represented in current nature reserves. With the addition of CONABIO's proposed areas, four of the five types remain underrepresented.

For Nuevo Leon, we found that the existing reserves are located primarily in regions with elevations between 1,000 and 1,500 m, slopes greater than 45%, and soils of low productivity (Litosols), with a temperate climate, and dominated by pine and oak forest cover types. The state's dominant physiographic region—low-elevation coastal plain with arid climate types and xeric scrub vegetation—is disproportionately underrepresented in the current reserve system. If the new protected lands were established, the largest gap would be in the low-elevation, level, coastal lands with xeric scrub communities.

The nature reserve areas proposed by CONABIO would greatly increase the protection of geographical features in Mexico and the states of Nuevo Leon and Tamaulipas. Whether this would also result in an increased protection of biodiversity remains unknown, as adequate maps of species distribution and detailed actual vegetation types are not available. However, gaps in the protective network would remain, particularly at the state level. Furthermore, establishment of additional nature reserve areas without sufficient funding to manage and protect them will not insure the long-term survival of these features and the species that reside in them.

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LAND COVER

Preclassification: An Ecologically Predictive Landform Model

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Introduction

The Southwest GAP Regional Land Cover mapping project faces the challenge of accurately mapping existing vegetation communities over a large (560,000 sq. mile) area by combining Landsat TM image classification techniques with GIS modeling. One of the most promising avenues by which a higher level of classification accuracy and community definition may be achieved, is to improve the modeling of biophysical parameters that predict potential vegetation. Mapping zones offer a way to partition the landscape into broad regions of similar spectral, ecological, and physiognomic characteristics (Manis et al. 2000). While mapping zones address stratification of macroclimate, microclimate and soil characteristics must be assessed to predict potential vegetation.

This article describes the development of a predictive landform model defined by slope gradient, slope aspect, landform position, hydrologic relationships, and microclimatic parameters. The ultimate objective of the model is to produce an ancillary GIS data set to assist imagery-based land cover classification.

Refining the Topographic Relative Moisture Index

The first step involves modeling parameters that influence surface and subsurface water movement and evaporative water loss versus water retention within local watersheds. For this step we modified and refined Parker's (1982) Topographic Relative Moisture Index (TRMI). The TRMI is a summed scalar index of four landscape elements derived from a Digital Elevation Model (DEM). These elements are *relative slope position*, *slope gradient*, *slope shape*, and *slope aspect*. The index works well in areas of moderate to high topographic relief. Parker (1982) acknowledges that the weighting of the elements is subjective, and different weighting schemes may be applied.

To refine the TRMI we incorporated two primary adjustments. First, we revised the original index to better assess the relationship between slope and aspect in affecting solar radiation and evaporation rates. The TRMI assumes a linear relationship between aspect and moisture availability independent of slope. Our refinement incorporates the assumption that soil moisture varies according to *both* the aspect and gradient of the slope. The greatest differences in soil moisture are between slopes of direct and opposite solar angles. To adjust for this range of solar angles we added an *aspect multiplier* based on the ranges of steepness of the slopes. This has the effect of assigning a more neutral index value to slopes that have less direct solar angles. The second modification involves rescaling the landform position, slope, and shape elements of the index with an aim toward building more discrete landform positions. Our revisions change the original TRMI scaling index of 0 to 60 (drier to wetter) to a more compact index ranging from 0 to 27 (drier to wetter). Figure 1 presents an example of the refined TRMI model.

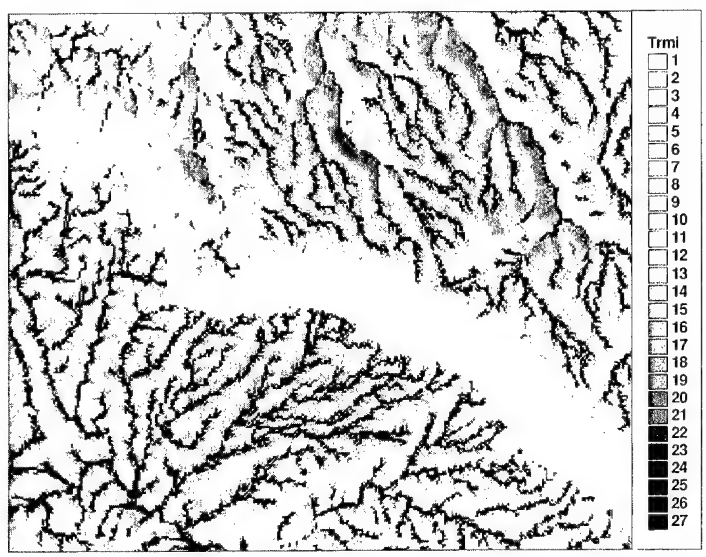

Figure 1. Refined Topographic Relative Moisture Index (TRMI) (1-27; drier – wetter).

Landform Position Model

Step two involves creating a landform position model that uses slope limits and TRMI values (Table 1). Landform Position Classes (LPCs) are therefore defined by topographic position, slope steepness, and relative moisture gradient. Landform classes are generic in nature, that is, no distinctions are made as to process or climatic zone. Flatter upland areas (i.e., plateaus, benches, divides, mesas, etc.) have medium TRMI values and low slope angles. Bottomlands, basins, etc. have a high TRMI and low slope angles. Similarly, other slope positions can be categorized in a range of steepness and relative moisture.

Table 1. Landform Position Classes

Landform Position Class		Slope Limit	Refined TRMI
1	Valley flats	lt 3 degrees	TRMI gt 22
2	Gently sloping toe slopes, bottoms, and swales	3-10 degrees	TRMI gt 18
3	Gently sloping ridges, fans, and hills	3-10 degrees	TRMI le 18
4	Nearly level terraces and plateaus	lt 3 degrees	TRMI le 22
5	Very moist steep slopes	10-35 degrees	TRMI ge 18
6	Moderately moist steep slopes	10-35 degrees	TRMI 11-17
7	Moderately dry steep slopes .	10-35 degrees	TRMI 4-10
8	Very dry steep slopes	10-35 degrees	TRMI lt 4
9	Cool aspect scarps, cliffs, canyons	gt 35 degrees	TRMI gt 10
10	Hot aspect scarps, cliffs, canyons	gt 35 degrees	TRMI le 10

Slope limits for the landform position model were derived empirically, using The Nature Conservancy's Ecological Land Unit (ELU) system's slope limits as a first iteration guide (The Nature Conservancy, unpublished manuscript). Modifications were tested to "best fit" the DEM-derived slopes to natural slope breaks. The result is 10 LPCs suitable for the 2 ha minimum polygon size suggested for the GAP final cover type classification. Figure 2 is an example of mapped LPCs.

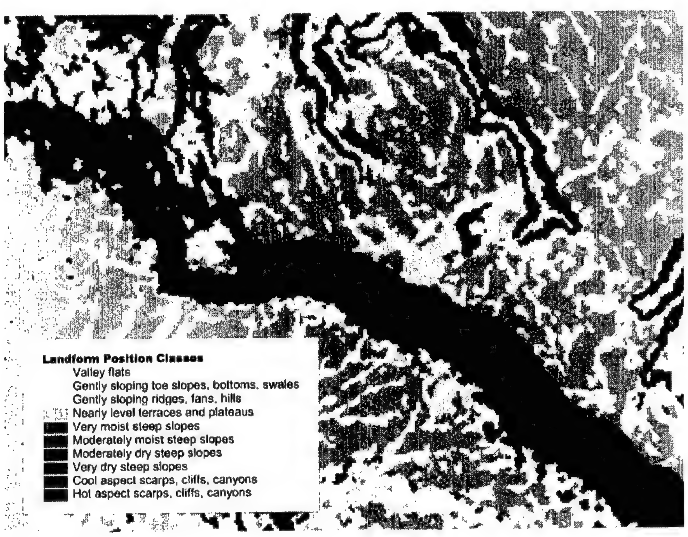

Figure 2. Landform Position Classes (LPC) showing southwest-facing escarpment.

Life Zone Stratification

In the final step, LPCs are reclassified into Ecologically Predictive Landform Classes (EPLCs) using a medium-scale, climatic zone (life zone) stratification. We experimented with elevation and STATSGO soil polygons, grouped by soil temperature, and other key criteria for a life zone stratification. While elevation data and STATSGO polygons hold some advantages, we ultimately chose a model by stratifying zones based on TM image-derived vegetation index as a superior strategy.

The Soil Adjusted Vegetation Index (SAVI) defines life zones by approximating vegetation leaf area from satellite imagery. This has important advantages over other methods but with at least two potential drawbacks. The most compelling advantage is that limits derived from a vegetation index do not appear arbitrary when applied to the landform model. Both the STATSGO and elevation-based stratification methods produced arbitrary life zone boundaries. We found that vegetation index values relate well to life zone (or life form) changes. Drawbacks to the method include the occurrence of "pixellated" zones near some stratification boundaries and incorrect classification of life zones due to recent fires or other large-scale disturbance features such as logging.

The pilot study area was the San Rafael Swell mapping zone, which includes the Capitol Reef and Henry Mountains. We used visual analysis of TM imagery, STATSGO, and elevation class to identify threshold SAVI values. These threshold values were classified to define four life zones. The lowest, driest zone is comprised of sparsely vegetated to barren, soft shale badlands. The second life zone is dominated by xeric dwarf shrubs and shrubs, low-cover xeric grasses, and low-cover pinyon-juniper on benchlands, slickrock plateau, and canyon country. The third zone represents the higher plateaus within the Swell, Capitol Reef, and the benches flanking the Henry Mountains that are dominated by high-cover pinyon woodlands and big sagebrush. The highest zone is the montane and subalpine communities on the slopes of the Henry Mountains.

Discussion

Thus, the output from the predictive landform model creates EPLCs based on topographic relative moisture, landform, and climatic zone (life zone). Steps one and two are created using a single ARC/INFO AML script. Step three utilizes an ERDAS Imagine EML script to combine the life zone stratification with the Landform Position Class model. After the stratification model is run, the initial output is filtered using ERDAS Imagine neighborhood analysis, majority filter, with a 3 x 3 window. This helps to smooth slope noise from the DEM, as well as remove isolated pixels. The number of life zone stratums can range from one to as many as five, depending on the complexity of the mapping zone microclimate. It is quite probable that all landform classes would not be present in some stratums. The number of life zone stratified landform classes or EPLCs is a multiplicative product of the number of life zones and the 10 LPCs. However, in some instances, it may be desirable to collapse similar landform classes if there is no essential differ-

ence in potential. For the San Rafael Swell mapping zone there are a total of 40 EPLCs.

Our EPLCs closely approximate the ELUs developed by The Nature Conservancy for conservation planning, as well as the Land Type level of ECOMAP (Cleland et al. 1997), and are easily crosswalked to those classifications-in-progress. We constrained our methodology to use only those data available regionwide to minimize processing time. The protocols described here for the EPLC model can be applied beyond the Southwest GAP land cover mapping effort. Other applications might include soil, habitat, hydrologic, and fire models.

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A Methodological Study for Accuracy Assessment of GAP Land Cover Maps

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Introduction

Quantifying the accuracy of a GAP land cover map involves comparing the thematic content of the digital map with corresponding thematic reference data (i.e., some form of "truth") obtained from the field. Typically, assessment locations are selected from the target area, and reference data are gathered from field visits or photo-interpretation (Congalton 1991). Methods of selecting assessment locations vary widely from purposive sampling, in which areas are intentionally selected for observation without applying a randomization mechanism, to selecting statistical samples from the entire target area or from some portion of the target area (e.g., roadsides). Sampling units may be areas (polygons) or points on the land. To analyze assessment data, a number of accuracy measures are available to compare the reference data and land cover maps (Stehman 1997). The choice of accuracy assessment methodologies is influenced by scientific, statistical, and operational concerns.

Ideally, accuracy estimates are based on unbiased samples and statistical estimation methods that provide a measure of the precision of the estimated accuracy rate. However, practical considerations such as targeting sample locations while maintaining geographic spread, choosing the appropriate observational unit, obtaining access to sampled locations, and minimizing travel costs all present challenges when designing such studies. Sample survey methodologies provide a design and estimation framework that balances statistical and operational considerations with study objectives (Cochran 1977, Salant and Dillman 1994, Thompson 1992). Probability sample designs can be developed to target areas requiring more intensive study, avoid areas that are difficult to access, or select clusters of observation units to reduce study costs. Contact methods used in survey sampling provide an effective method of gaining access to private land and minimizing bias from nonresponse. Just as a questionnaire provides a rigorous basis for repeatability in telephone surveys, field observation methods are based on protocols that encourage well-defined observations at the correct location while minimizing the effort required to collect reference data. Estimators that take into account survey methods used in a study are readily available from this framework.

In response to a request from EPA Region 7 for an integrated accuracy assessment plan in the region, we designed and conducted a pilot study using a sample survey approach to assess the accuracy of GAP land cover maps. The goal was to produce a statistically sound and operationally feasible design that meets GAP's accuracy assessment objectives. In particular, we were interested in proto-

cols for gaining permission to sample on private land, protocols for observing reference land cover in the field, appropriate sample design and estimation strategies, and quantifying the operational resources required to do a full accuracy assessment.

In this paper, we focus on the Iowa pilot study. We briefly summarize the methods we used to address scientific, statistical, and operational considerations, and present pilot study results. Further details are available in Nusser and Klaas (2001). Finally, we discuss the implications of this design for future accuracy assessment efforts.

Sample Design

The pilot study was conducted during the summer of 1999 in four northeast counties in Iowa: Allamakee, Clayton, Fayette, and Winneshiek.

A stratified two-stage cluster sample design (Lohr 1999) was used to select sample pixels for field visits from the four-county study area. We first selected USGS 7.5 degree quadrangles (or combinations of partial quads that fell on the border of the study area) as primary sampling units (PSUs) (Figure 1). Five strata of 8-12 PSUs each were created to ensure geographic spread of the PSUs and coverage of all land cover categories. Two PSUs were randomly selected from each stratum using systematic sampling, for a total of ten PSUs.

Individual pixels were selected from PSUs in a second stage of sampling. Resource constraints dictated sample size. Iowa staff had a goal of visiting 200 points within the study area. Since we expected that access would be denied for approximately 15% of the sample points, 236 sample points were selected to achieve 200 responses. Pixel samples were selected from the ten PSUs using a stratified design. The pixel sample was stratified according to nine relatively homogeneous land cover categories, collapsed from the original 29 vegetation classes defined for Iowa (Table 1).

To determine the allocation of sample pixels across land cover categories, we used a square root rule that balanced the need for estimates corresponding to the entire study area with the desire to obtain estimates for the defined land cover categories. We incorporated an adjustment factor for increased sample size in challenging land covers, and reduced sample size for land covers that were easier to classify. We then applied minimum (n=16) and maximum (n=44) sample sizes per stratum. The full list of pixels for a given land cover category was sorted by PSU, latitude, and longitude (to encourage geographic spread of the sample pixels), and a systematic sample was selected (Figure 2).

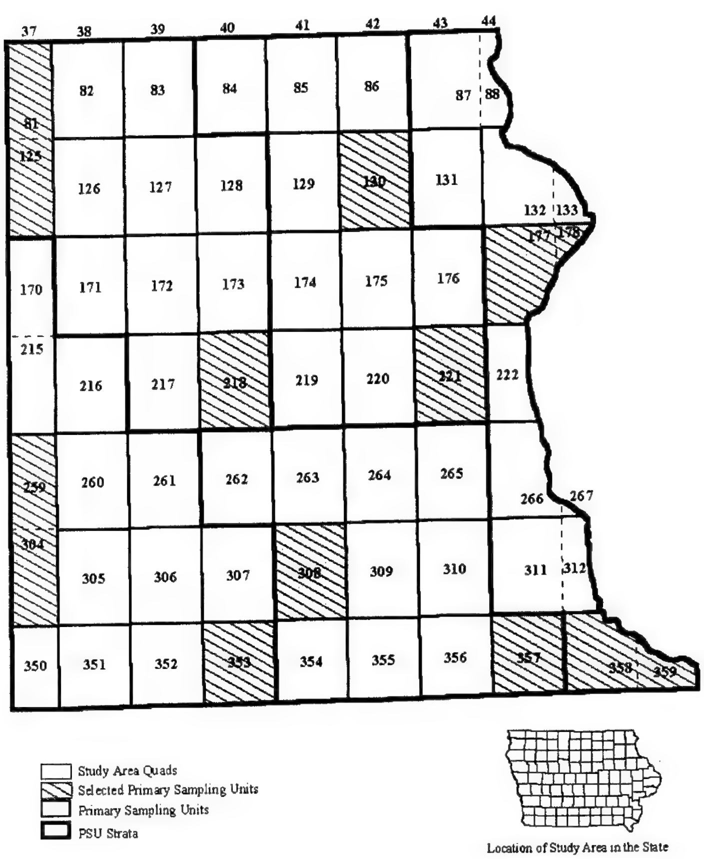

Figure 1. Accuracy assessment study area in Iowa, partitioned into quads and primary sampling units (PSUs), which are quads or combinations of partial and/or whole quads. Sampled PSUs are shaded.

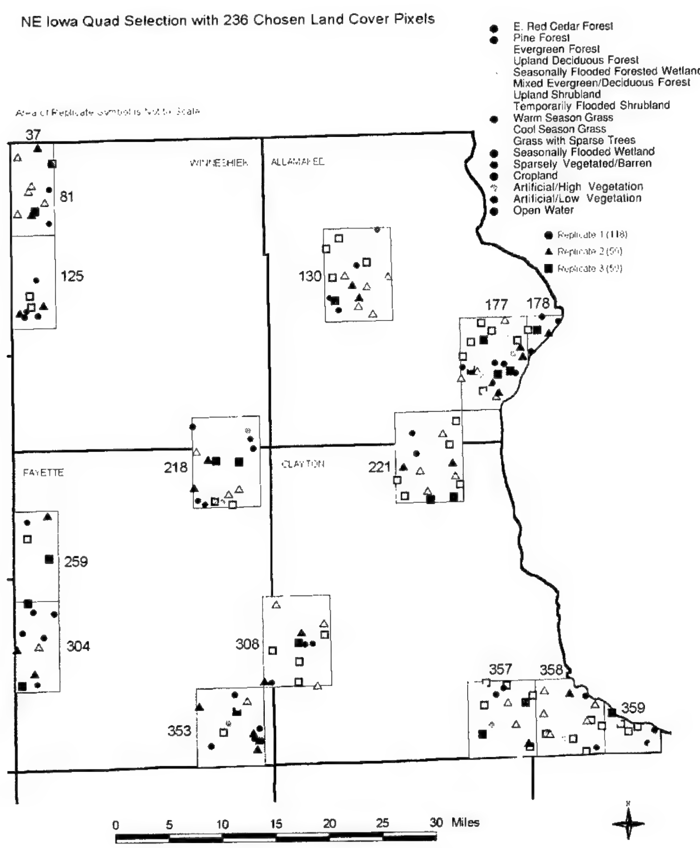

Figure 2. Sampled primary sampling units and sampled pixels by land cover. Numeric labels denote quad identification. Subsamples are denoted by symbols, as shown in the legend.

Table 1. Estimated accuracy rates by land cover category using nine-pixel cluster data.

Land Cover Category[a] (*s*)	Total Area with Consistent Field and Map Classifications (ha)	Estimated Field Area (ha)	Producer's Accuracy (%)			Map Area (ha)	User's Accuracy (%)		
			$\hat{PA}(s)$[b]	(se)	*n*		$\hat{PA}(s)$[c]	(se)	*n*
Coniferous Forest	326	5,464	5.9	(1.9)	83	1,362	23.9	(9.5)	72
Deciduous Forest	91,902	128,660	71.4	(3.7)	381	146,846	62.5	(3.4)	371
Mixed Forest	153	1,204	12.7	(8.7)	23	2,635	5.8	(2.9)	69
Coniferous Woodland	0	43	0.0	-	1	0	-	-	
Deciduous Woodland	0	32,890	0.0	0.0	57	0	-	-	
Mixed Woodland	0	3,376	0.0	0.0	11	0	-	-	
Shrubland	0	13,610	0.0	0.0	8	5,202	0.0	0.0	75
Grass	7,795	13,659	57.1	(7.4)	55	112,282	6.9	(1.5)	247
Sparsely Vegetated/Barren	0	1,381	0.0	0.0	13	1,723	0.0	0.0	36
Artificial (roads, urban)	3,456	32,432	10.7	(3.5)	136	3,678	93.9	(3.3)	45
Cropland	402,789	499,237	80.6	(2.1)	536	451,658	89.2	(2.1)	347
Open Water	9,700	10,700	90.7	(4.6)	73	17,270	56.2	(5.1)	115
Total	516,121	742,656				742,656			

[a] Land cover categories were defined by combining Iowa vegetation classes as follows: *coniferous forest* = pine forest, eastern red cedar forest, evergreen forest; *deciduous forest* = upland deciduous forest, temporarily flooded forested wetland, seasonally flooded forested wetland; *mixed forest* = mixed evergreen and deciduous forest; *coniferous woodland* = eastern red cedar woodland; *deciduous woodland* = upland deciduous woodland, temporarily flooded deciduous woodland, seasonally flooded deciduous woodland; *mixed woodland* = mixed evergreen and deciduous woodland; *shrubland* = upland shrub, temporarily flooded shrub, seasonally flooded shrub, semi-permanently flooded shrub, saturated shrub; *grass* = warm season grass/perennial forbs, temporarily flooded wetland, seasonally flooded wetland, semi-permanently flooded wetland, saturated wetland, permanently flooded wetland; grassland with sparse shrubs and trees; *sparsely vegetated/ barren* = a single vegetation class that includes open bluff/cliff, talus slopes, mud, sand, soil; *artificial* = artificial with high vegetation, artificial with low vegetation; *agriculture* = cool season grass, cropland; *open water* = a single vegetation class. The woodland land cover categories were not present on the land cover map, but were observed in the field during the study.

[b] Producer's Accuracy is the probability that a pixel observed in the field is correctly depicted on the map.

[c] User's Accuracy is the probability that a pixel on the map correctly identifies the land cover category as it exists in the field.

Because the time required to collect field data was not well known, the sample was divided into three balanced subsamples, corresponding to 50%, 25%, and 25% of the full sample, so that each balanced fraction of the sample could be completed and a decision made about resources availability for completing the next subsample. Field observers were instructed to complete samples from subsample 1 (50% sample) prior to collecting data on subsample 2, and were given similar instructions for subsample 3. In practice, these guidelines were implemented within county boundaries.

Obtaining Permission to Access Land

Owner information and the Public Land Survey (PLS) location for each sample pixel were obtained from offices of the County Auditor or Assessor. These offices are responsible for assessing property taxes and thus have the most recent information on land ownership. Plat directories and local phone directories were used to determine addresses and phone numbers for each landowner. Less than 10 of 236 addresses and ownerships were incorrect or had changed between the time of determination and the start of field work.

Of the 236 sample pixels, 198 were located on private property and 38 were on state or federal lands or were within city limits of towns. Letters requesting access to land were prepared using Iowa State University letterhead and mailed to each of the 198 private landowners along with a color land cover map of their county as a gift. Landowners returned 90 letters (45.4%) and 87 of these granted permission to enter their property. The day prior to visiting a site, a follow-up phone call was made to the landowner, regardless of whether a letter had been received or not, resulting in an additional 58 landowners who granted access and 8 who denied access. Due to insufficient time and resources, no follow-up calls or visits were made to 42 landowners in subsamples 2 and 3 in Fayette County and subsample 3 in Clayton County.

Field Assessment

Selected target pixels were located in the field by orienteering to the general vicinity of a point using the prepared topographic maps and then navigating to the exact coordinates of a point using a geographical positioning system (GPS) receiver with automatic differential correction capabilities. The GPS displayed a confidence interval from the desired coordinates that was usually less than five meters. Land cover was assessed for the target pixel (30 x 30 m) and the eight adjoining pixels using a list of codes for the 29 mapped vegetation classes in Iowa. A total of 18 points located on the floodplain of the Mississippi River were accessed with an air boat provided by the U.S. Fish and Wildlife Service.

Analysis

Field and map land cover data were used to estimate standard accuracy assessment rates (Congalton 1991), including the overall accuracy rate and the producer's and user's rates for each of 12 land cover categories. These corresponded to the nine preselected strata plus three additional woodland categories identified in the field but not present on the map. Two sets of analyses were performed to consider trade-offs in data collection effort and precision, one using all nine pixels from each of the 153 clusters (nine-pixel data) and a second based only on center pixels (center-pixel data).

Because an unequal probability sample design was used, and nonresponse occurred for some sample pixels, two sets of sample weights were calculated for use with center-pixel data and nine-pixel cluster data, respectively. A ratio adjustment was used to create weights that generate the map area for each land cover category when weights for points in the map land cover category are summed (Nusser and Klaas 2002).

To compare field-observed and map-determined land cover categories, weighted estimates of standard accuracy measures were calculated using estimators that were modified to incorporate sampling weights (Nusser and Klaas 2002). Variance estimates were obtained using PROC SURVEYMEANS in SAS (http://www.sas.com/rnd/app/da/new/802ce/stat/chap14/sect3.htm), accounting for pixel clusters and map land cover category strata. Domain estimation was used for estimating user's and producer's accuracy rates.

Results

Overall accuracy was estimated to be 69.5% (s.e. = 2.0) using the nine-pixel cluster data. The estimated accuracy rates for nine-pixel data varied greatly across land cover categories (Table 1). For example, the producer's accuracy is quite high for artificial and cropland categories but is poor for coniferous forest and especially for shrubland and sparse vegetation, all of which have relatively small map surface areas. A similar level of variation was observed in estimates of user's accuracy; water had a high accuracy rate, and smaller land cover classes had relatively poor accuracy. Three woodland land cover categories (coniferous, deciduous, mixed) were found in the field but were not present on the map. Mismatches

Table 2. Observed number of pixels in nine-pixel data, by field and map land cover category. [a]

Field Land Cover Category	Map Land Cover Category												
	Conif. Forest	Decid. Forest	Mixed Forest	Conif. Wdlnd	Decid. Wdlnd	Mixed Wdlnd	Grass	Shrub-land	Sparse Veg.	Artifi-cial	Crop-land	Open Water	Total
Coniferous Forest	39	29	15	0	0	0	0	0	0	0	0	0	83
Deciduous Forest	17	235	44	0	0	0	2	36	0	0	19	28	381
Mixed Forest	6	6	4	0	0	0	0	5	1	0	0	1	23
Coniferous Woodland	0	0	1	0	0	0	0	0	0	0	0	0	1
Deciduous Woodland	4	36	1	0	0	0	0	11	1	0	3	1	57
Mixed Woodland	2	8	0	0	0	0	0	0	0	0	1	0	11
Shrubland	0	1	0	0	0	0	0	3	0	0	4	0	8
Grass	1	10	0	0	0	0	0	23	0	0	3	18	55
Sparsely Vegetated/ Barren	0	0	0	0	0	0	0	8	0	4	0	1	13
Artificial (roads, urban)	0	4	2	0	0	0	1	40	3	41	44	1	136
Cropland	3	38	2	0	0	0	72	118	28	0	273	2	536
Open Water	0	4	0	0	0	0	0	3	3	0	0	63	73
Total	72	371	69	0	0	0	75	247	36	45	347	115	1,377

[a] Examining the table across rows shows how a land cover category observed in the field is categorized on the map (related to Producer's Accuracy). Examining the table by columns shows how map land cover categories are categorized in the field (related to User's Accuracy).

between the field and map land cover categories were often associated with related land cover categories (Table 2). For example, pixels classified as woodland in the field were usually classified as forest on the land cover map. Pixels classified in the field as shrubland and sparse vegetation were often classified as herbaceous on the map.

Analyses using data from center pixels reflected similar estimates relative to the nine-pixel data but typically generated larger standard errors. The estimated overall accuracy of 64.0% (s.e. = 6.3) is not statistically different from the nine-pixel estimate but has an estimated standard error three times that of the nine-pixel estimate. Most single-pixel accuracy rate estimates (Table 3) were within ten percentage points of the nine-pixel estimates. The largest differences were found with smaller land cover categories, where a reduction in sample size had a relatively large effect. The center-pixel producer's accuracy estimate for mixed forest was 0%, because map and field-determined mixed forest pixels were never in agreement at a center pixel, whereas field and map matches for mixed forest were observed with nine-pixel data.

Nine-pixel cluster data clearly provides additional information for rare cover classes, as shown by the greater number of nonzero cells in the nine-pixel map by field matrix relative to the center-pixel matrix (Table 4). Standard errors for center-pixel estimates generally ranged from 1.5 to 4.5 times higher than the nine-pixel standard errors, with most being about triple the size of the nine-pixel estimates. For producer's accuracy estimates, one standard error (coniferous forest) was over ten times higher than the corresponding nine-pixel estimate, while one other (grass, water) was half of the nine-pixel standard error. This may be due in part to the dependence of the variance estimate on the estimated percentage. These results indicate that substantial gains in precision were generally obtained by observing additional data.

Table 3. Estimated accuracy rates by land cover category using center-pixel data.

Land Cover Category[a] (s)	Total Area with Consistent Field and Map Classifications (ha)	Estimated Field Area (ha)	Producer's Accuracy (%) $\hat{PA}(s)$[b]	(se)	n	Map Area (ha)	User's Accuracy (%) $\hat{PA}(s)$[c]	(se)	n
Coniferous Forest	599	5,957	10.1	(9.2)	9	1,362	43.9	(13.5)	14
Deciduous Forest	86,268	137,375	62.8	(12.3)	43	146,846	58.7	(9.1)	30
Mixed Forest	0	310	0.0	(0.0)	2	2,635	(0.0)	(0.0)	14
Coniferous Woodland	0	187	0.0	-	1	0	-		0
Deciduous Woodland	0	42,397	0.0	(0.0)	6	0	-		0
Mixed Woodland	0	5,081	0.0	(0.0)	2	0	-		0
Shrubland	0	21,827	0.0	-	1	5,202	0.0	(0.0)	17
Grass	13,111	19,986	65.6	(19.9)	6	112,282	11.7	(6.4)	26
Sparsely Vegetated/Barren	0	365	0.0	-	1	1,723	0.0	(0.0)	9
Artificial (roads, urban)	3,313	37,267	8.8	(6.1)	15	3,678	90.1	(9.5)	10
Cropland	364,349	463,759	78.6	(5.6)	60	451,658	80.7	(8.5)	20
Open Water	7,971	8,145	97.8	(2.2)	7	17,270	46.1	(13.9)	13
Total	516,121	742,656				742,656			153

[a] Land cover categories were defined by combining Iowa vegetation classes as follows: *coniferous forest* = pine forest, eastern red cedar forest, evergreen forest; *deciduous forest* = upland deciduous forest, temporarily flooded forested wetland, seasonally flooded forested wetland; *mixed forest* = mixed evergreen and deciduous forest; *coniferous woodland* = eastern red cedar woodland; *deciduous woodland* = upland deciduous woodland, temporarily flooded deciduous woodland, seasonally flooded deciduous woodland; *mixed woodland* = mixed evergreen and deciduous woodland; *shrubland* = upland shrub, temporarily flooded shrub, seasonally flooded shrub, semi-permanently flooded shrub, saturated shrub; *grass* = warm season grass/perennial forbs, temporarily flooded wetland, seasonally flooded wetland, semi-permanently flooded wetland, saturated wetland, permanently flooded wetland; grassland with sparse shrubs and trees; *sparsely vegetated/barren* = a single vegetation class that includes open bluff/cliff, talus slopes, mud, sand, soil; *artificial* = artificial with high vegetation, artificial with low vegetation; *agriculture* = cool season grass, cropland; *open water* = a single vegetation class. The woodland land cover categories were not present on the land cover map, but were observed in the field during the study.

[b] Producer's Accuracy is the probability that a pixel observed in the field is correctly depicted on the map.

[c] User's Accuracy is the probability that a pixel on the map correctly identifies the land cover category as it exists in the field.

Table 4. Observed number of pixels in center-pixel data, by field and map land cover category.[a]

Field Land Cover Category	Map Land Cover Category: Conif. Forest	Decid. Forest	Mixed Forest	Conif. Wdlnd	Decid. Wdlnd	Mixed Wdlnd	Grass	Shrub-land	Sparse Veg.	Artifi-cial	Crop-land	Open Water	Total
Coniferous Forest	6	1	2	0	0	0	0	0	0	0	0	0	9
Deciduous Forest	5	18	9	0	0	0	0	5	0	0	1	5	43
Mixed Forest	1	0	0	0	0	0	0	0	0	1	0	0	2
Coniferous Woodland	0	0	1	0	0	0	0	0	0	0	0	0	1
Deciduous Woodland	1	3	0	0	0	0	0	1	0	0	1	0	6
Mixed Woodland	1	1	0	0	0	0	0	0	0	0	0	0	2
Shrubland	0	0	0	0	0	0	0	0	0	0	1	0	1
Grass	0	1	0	0	0	0	0	3	0	0	0	2	6
Sparsely Vegetated / Barren	0	0	0	0	0	0	0	0	0	1	0	0	1
Artificial (roads, urban)	0	0	1	0	0	0	0	3	9	1	1	0	15
Cropland	0	6	1	0	0	0	17	14	0	6	16	0	60
Open Water	0	0	0	0	0	0	0	0	0	1	0	6	7
Total	14	30	14	0	0	0	17	26	9	10	20	13	153

[a] Examining the table across rows shows how a land cover category observed in the field is categorized on the map (related to Producer's Accuracy). Examining the table by columns shows how map land cover categories are categorized in the field (related to User's Accuracy).

Discussion

A primary goal of this pilot study was to explore the use of the sample survey approach in accuracy assessment, including sample design, owner contact, field data collection, and analysis. A sample design was developed to balance operational and statistical considerations and to cover the entire study area, regardless of accessibility. The stratified two-stage cluster sample design worked well to control sample sizes for map land cover categories and to encourage geographic spread across and within PSUs. The design proved sufficiently flexible that it was easily adapted for two neighboring states (Nusser and Klaas 2002).

Early in the project design phase, we discussed alternative definitions for the first-stage sampling unit, or PSU. A quad sheet (or quarter quad) has been used in the past as a sampling unit at this stage for other GAP accuracy assessment studies. Quad sheets provide an operational advantage in reducing travel time and workload relative to a systematic or simple random sample, but are sufficiently large to avoid overly clustered second-stage samples that reduce the statistical efficiency of the design. A second alternative is to define the PSU as a county or a portion of a county, which has similar properties but would provide significant operational efficiencies when identifying landowners.

The choice of a pixel as the second-stage sampling unit was simple to work with in the sampling process. The stratum identification provided the control needed to address sample size requirements for strata, and the allocation strategy allowed us to balance estimation goals for land cover classes. The gain in precision of accuracy estimates obtained from the nine-pixel design and the increased ability to gather data for rare land covers were deemed well worth the extra effort required to observe land cover for each of the pixels in the 3 x 3 pixel clusters.

The pilot study demonstrated the need to accurately locate the pixel. Without precise positioning, field staff may visit a pixel with a map land cover category different from the category associated with the true location of the selected pixel and destroy the control provided by stratification for land cover categories.

Protocols for contacting landowners had a large effect on the response rates in the study. Several attempts were made to contact landowners and different contact modes (e.g., telephone, mail) were used to improve response rates. Key strategies included using Iowa State University letterhead (rather than federal agency letterhead), explaining the study and its significance to Iowa and the landowner, offering a printed map of the area as a gift, and calling the landowner before the visit to remind him/her of the project to seek permission if needed. These protocols are derived from proven sample survey methodologies that are known to maximize response rates (Salant and Dillman 1994).

One of the advantages of the design used is that all land was eligible to be assessed for accuracy, and thus the results apply to the

entire target area. Although few areas are physically inaccessible in the Midwest, there is still a need to develop ground-truthing methods for inaccessible or otherwise unobservable sample units. For example, aerial photography may provide a surrogate material for unobservable units.

A major concern with the current pilot study was the use of 1999 field data to assess the accuracy of a land cover map derived from 1992 imagery. Large changes in land cover can occur in this time span that confound assessments of the digital map.

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An Evaluation of Helicopter Use for Collecting Land Cover Data for Southwest ReGAP in Colorado

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As a part of the Southwest Regional Gap Analysis Project, the Colorado Division of Wildlife (CDOW) and U.S. Bureau of Land Management (BLM) conducted an evaluation of helicopter-based methods for collecting ground-truth reference information and compared this methodology to collecting data via automobile and on foot. These data are used for classifying Landsat-7 Enhanced Thematic Mapper satellite imagery in developing a land cover map of a five-state region in the Southwest. It was found that although more expensive than traditional ground-based collection of field data, the helicopter method had some advantages.

Background

The Southwest Regional Gap Analysis Project (SW ReGAP) is attempting to create a high-resolution, seamless land cover map of Arizona, Colorado, Nevada, New Mexico, and Utah using Landsat-7 TM satellite imagery, field data, digital elevation models, and other spatial data. Thematic categories are based on the National Vegetation Classification System (NVCS) (Anderson et al. 1998, Grossman et al. 1998, Jennings et al. 2002). To evaluate efficient methods for collecting training site data for the land cover classification process, we compared training site data collection by helicopter, as has been used by the BLM in Alaska, to a more traditional method of travel by automobile and on foot to visit sample sites of each land cover type. Mission planning time, mission execution logistics, methodological efficiencies, and cost considerations were evaluated and compared.

Study Site

The study site for the helicopter data collection evaluation was within the Southern Piedmont Mapping Zone, a SW ReGAP defined ecoregion (Manis et al. 2000) on the southeastern plains of Colorado near La Junta. Since Landsat TM-7 imagery was not yet available for use in the evaluation, 1995 Landsat-5 TM was utilized. The helicopter method evaluation was conducted over three days from June 11-13, 2001. This method of data collection was compared to data collected by traveling by automobile and on foot throughout the summer of 2001 (July through October) over the entire Southern Piedmont and some adjacent high plains mapping zones.

Methods

First, for the helicopter protocol, a "ground school" was held to provide aircraft safety training for participating field personnel. Then, field sites to be visited were selected using an ArcViewII Avenue script (O'Brien and Schrupp 2001) designed to randomly select 10 field sites per each of 58 spectral cluster classes of a mini-

mum size (2 ha) and of a specified distance either close to or far from roads (50 meters). The 58 cluster classes were generated from an unsupervised classification of a two-date, six-band, merged data set of Landsat-5 imagery (June 21, 1995, and September 25, 1995) and delineated a set of spectrally homogeneous land cover patches. Once selected, the target sites were transferred to 1:100,000 scale BLM Surface Management Series Status maps, and digital files of the geographic coordinates of the centers of each site were uploaded to a GPS receiver to aid in the helicopter navigation. Field personnel from the Colorado component of SW ReGAP and the Colorado Vegetation Classification Project collected the site data. The same computer programs and laptops that were used for collecting site data via ground methods were used for recording data from the helicopter.

The helicopter method for accessing ground control points was similar to one used by agencies in Alaska. The helicopter would travel to each target field site and either land or hover over the site, depending upon landowner access considerations. Each "mission" was typically less than 2 hours of air time, including team rotation and refueling. Coordinates of the target field sites selected for each mission were loaded onto a GPS unit before each crew rotation. Following BLM aircraft safety guidelines, the helicopter's ground movement was shadowed by ground teams that provided for air-to-ground communication between the pilot, the aviation fuel manager, and the Safety Management crew.

GPS units were used to navigate to each field site where data were collected. These data were later used to classify the site to the Alliance level of the NVCS. One to four digital photos were taken at each site, from either right or obtuse angles, generally at heights of 90 m and 30 m above the site. Descriptive information for each site was catalogued on a field form, and associated photo numbers were catalogued on the field form, the navigator's map, or both.

The methods for collecting site data by travelling by automobile and on foot were similar to the helicopter methods, except that, obviously, we could not hover over a site. As much of the land on the plains of Colorado is in private ownership, crews were prevented from walking out onto many of the sites, and land cover had to be described from the roadside.

Results

Costs for the helicopter protocol were tracked via BLM's standard "Aircraft Services Reimbursement" procedures for helicopter costs. Costs included ferry time of the helicopter from its home base in Englewood, Colorado, to the study site in La Junta, aircraft time while conducting field sampling, personnel time of both the pilot and aviation fuel manager, and per diem for the air crew. There were additional costs for field crew time, per diem, and vehicles. Both CDOW and BLM contributed personnel time towards the evaluation.

Eight crew rotations were performed during the helicopter evaluation on June 12 and 13 (two on the 12th and six on the 13th). Problems were experienced with the Trimble Geo-Explorer III GPS unit, which took about half the day of the 12th to resolve. Ultimately, the pilot's Garmin unit was used for navigation to the field sites. In summary, 9.2 hours (3.5 hours on 06/12/01 and 5.7 hours on 06/13/01) at $750/hour were spent aloft, visiting 48 sites over the two days of site description activity (13 on the 12th and 35 on the 13th). Costs for visiting field sites by helicopter averaged $228/point over the two days. Helicopter costs alone (the most significant component of the project) averaged $265/point for the first day and $145/point for the second day.

By comparison, it would have taken approximately 54 hours to visit these sites by automobile and on foot. Costs of traditional data collection were extrapolated from costs of 39 field days spent during four months of field work, from July to October of 2001. The average number of sites visited during these trips was nine per day. Costs for visiting these sites by automobile and on foot averaged $72/point.

Discussion

About half a day was wasted dealing with GPS and site coordinate problems, while money was being spent for helicopter personnel time. This increased the overall cost of each field point collected using the helicopter method. Once these problems were resolved on the second day, the costs per site visit came down to what we feel should be expected for this type of operation. The costs for the helicopter method were higher compared to traditional methods; however, many more sites were visited per day, and better land cover classifications were obtained through better access to the sites and the ability to view sites from above, as the satellite does, and make better cover estimates.

Some observed benefits of the helicopter methodology were:

1. A synoptic view of the field site; more in keeping with the view-angle of the satellite than of ground-based field crews.
2. Access to field sites that could not have been visited from the ground, given the sparseness of roads in southeastern Colorado and the amount of privately held land.
3. Efficiencies of travel time to and from field sites.

Some lessons learned from this prototype were:

1. Verify the coordinates of field points to be loaded to the navigational GPS unit and test the procedures for doing so.
2. Make sure the coordinate system used on the GPS unit are the same as those used by the helicopter pilot.
3. Make sure the GPS equipment has a robust antenna system and all field crew members are versed in its operation. Have a hard copy of the GPS operator's manual in hand.
4. Download and catalogue digital photos each evening.
5. Upload and check the next day's field targets the evening before.

Future Considerations

While the helicopter data collection methodology is relatively expensive, it affords some benefits not achievable with a ground-based methodology, and the cost/benefit ratio may be improved through careful planning. The BLM and the US Forest Service often post helicopters at remote locations for readiness in the event of wildfires throughout the fire season, and there may be cost benefits realized by scheduling such craft when they are not being used to fight fires. Even at the standard rate, helicopter use to visit a subset of field sites may be the most efficient way to build a high-quality photo-interpretation key to the land cover types being classified. This research did not include a cost-benefit evaluation of using aerial photographs or videos taken from fixed-wing aircraft, in combination with ground reconnaissance.

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ANIMAL MODELING

Modeling Reptile and Amphibian Range Distributions from Species Occurrences and Landscape Variables

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Introduction

An international symposium in October 1999 demonstrated the state of the art in modeling species occurrences (Scott et al. 2001). One clear message from the symposium was the broad diversity of approaches that constitute the state of the art. No single method excels, largely because of the very particular and local nature of the problem. Organisms both influence and respond to their local environment; thus, the same species may key in on different resources in different landscapes. Furthermore, modeling methods vary widely in their "transparency," which can inhibit transportability or robustness.

In order to provide an analytical modeling framework that is transparent and durable, we have chosen to use recursive partitioning methods to develop "objective" semi-empirical models of wildlife-habitat relationships for the Nebraska Gap Analysis Project. Recursive partitioning aims to predict membership of individual cases (here, species occurrences) in classes of a categorical dependent variable from measurements of one or several independent variables (here, land cover, soils, climate, etc.). The motivation for using this strategy is twofold: (1) the resulting trees of decision points and values that form the models are readily understandable, debatable, and tunable; and (2) its non-parametric modeling handles the multimodality likely to be found in species occurrence data.

A recent review (Guisan and Zimmerman 2000) notes that although dichotomous trees are commonly employed in systematic biology for keys to species identification, regression techniques to generate these trees have rarely been used to model occurrences of vertebrate species. Several recent papers have used CART (Classification and Regression Trees: Breiman et al. 1984) to develop habitat models. Iverson and Prasad (1998) used CART models to predict tree species distributions under climate change scenarios. Rejwan et al. (1999) used CART to model smallmouth bass (*Micropterus dolomieui*) habitat. McKenzie et al. (2000) used CART to estimate regional fire return intervals across the Columbia River Basin from local data sets. De'ath and Fabricius (2000) provided a tutorial of CART modeling using habitat relationships of soft coral taxa in Australia. Anderson et al. (2000) used CART to develop a habitat model for the desert tortoise (*Gopherus agassizii*). They found that the CART method could handle complicated interactions between variables that stem from spatial autocorrelations and spatial associations. They argued that while the CART model was phenomenological and not mechanistic, it provided valuable insight into the organism's habitat requirements and laid the foundation for further studies.

A drawback of the CART algorithm is computational complexity and thus computer time. A recent improvement on the CART algorithm is QUEST (Quick, Unbiased, and Efficient Statistical Trees; Loh and Shih 1997), which greatly speeds up searching of the data space and which is more robust in the face of categorical variables with many levels. A comparative study of 33 classification algorithms has shown that QUEST ably combines speed with accuracy (Lim et al. 2000).

Amphibians and reptile occurrence data were used to develop, test, and refine objective semi-empirical models. The paper illustrates the modeling procedure, the model tree and resulting range distribution for an amphibian species (*Eumeces multivirgatus*), and discusses the weaknesses and strengths of the framework.

Data

Numerous environmental variables were calculated and tessellated statewide using a hexagonal coverage produced by the EPA EMAP program. The resolution of the hexagons is approximately 40 km^2 within Nebraska. Each variable was rescaled from a raster format (30 m or 1500 m) to the coarser "modeling" hexagonal coverage by performing calculations within each unique hexagon. The variables were expressed as a percent composition, an average, a weighted average, or a categorical class.

Percent composition of land cover classes was derived from the Nebraska Gap Analysis Project land-cover data set (see Henebry et al. 2000). Soil data were derived from the Nebraska State Soil

Geographic Database (STATSGO) and map. Soil texture groups were cross-walked into five classes: coarse, moderately coarse, medium, moderately fine, and fine. The previously mentioned data and hydric soils were then calculated as a percentage.

Terrain data used in the data set were calculated from United States Geological Society Digital Elevation Models (DEMs). Elevation averages were calculated within each hexagon. Slope data was divided into six percentage classes: 0-2, 2-5, 5-10, 10-15, 15-20, and >20. These classes were expressed as a percent composition. A buffered stream data set was developed to create a binary class variable (presence/absence).

Climate data were acquired from weather stations throughout the state of Nebraska and selected stations from surrounding states. Means and coefficients of variation (CV%) were calculated for monthly average precipitation and monthly average, minimum, and maximum temperatures. Total average quarterly and growing season precipitation, growing degree days, and frost-free days were also calculated. These data were submitted to a robust interpolation algorithm (nngridr; Watson 1994) and output as raster coverages. These data sets were then averaged within each modeling hexagon.

Voucher specimens of amphibians and reptiles collected in Nebraska since 1969 were obtained from the Nebraska State Museum and used for the occurrence data. Older legal descriptions were translated into latitude and longitude with a spatial accuracy of approximately one quarter-section (ca. 65 ha).

Methods

Voucher specimen data sets were queried from a database and converted to a point coverage (Figure 1). The observation points and modeling hexagonal coverage were intersected and the associated hexagon values attributed to the intersecting point coverage. Variables for each specimen point were submitted to the QUEST software program. An inversion for each species was developed from the output classification tree (Figure 2). Trimming of the classifi-

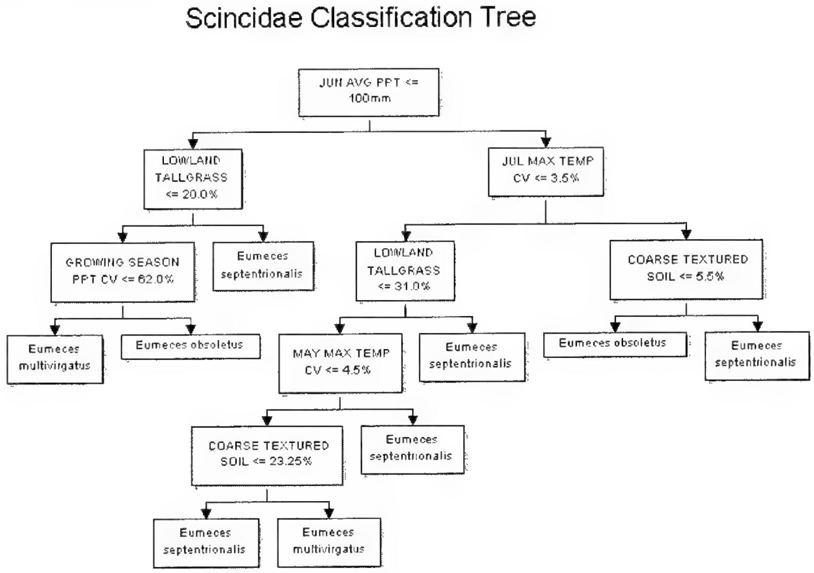

Figure 2. Classification tree for three skink species in Nebraska.

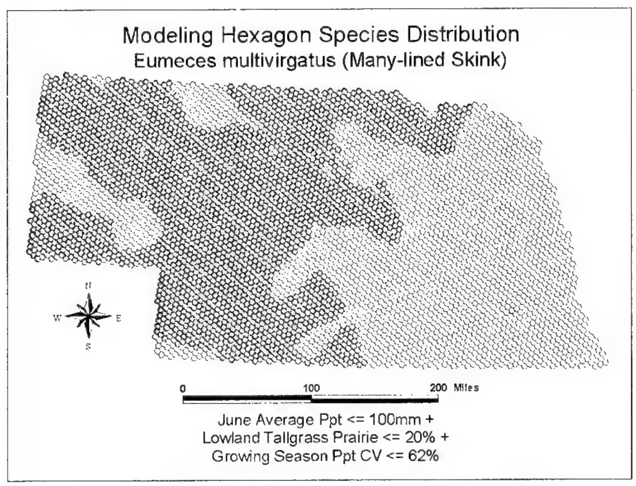

Figure 3. Model inversion produces the habitat distribution map.

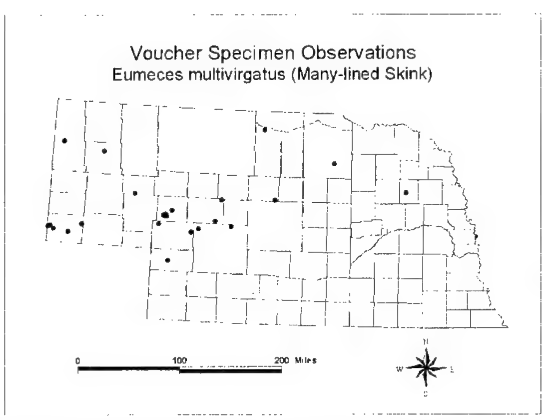

Figure 1. Occurrence data from georeferenced voucher specimens.

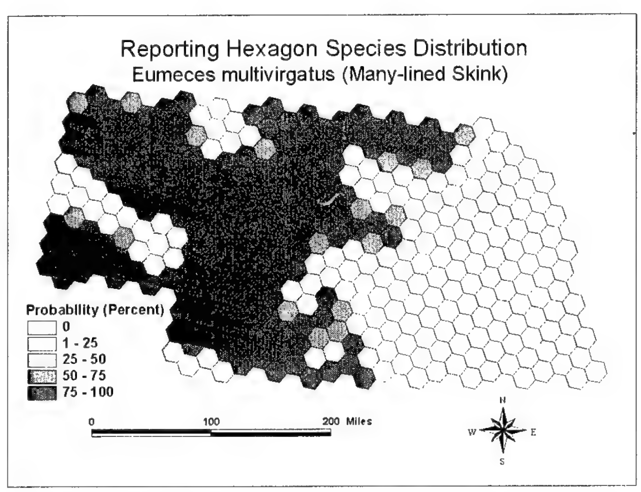

Figure 4. Probability of encountering species' modeled habitat.

cation leaves was done through a query of the modeling hexagonal coverage to determine appropriate tree splits for each species (Figure 3).

The queried modeling hexagons were intersected with a coarser resolution (ca. 650 km^2) "reporting" hexagonal coverage. Percent probability was determined by the percent area of the modeling hexagons within each unique reporting hexagon. The reporting hexagonal coverage expresses the probability of finding suitable habitat within each particular hexagon (Figure 4).

Discussion

The QUEST algorithm rapidly (within seconds) produced candidate models from groups of species occurrences, including model cross-validation calculations. The time-consuming step in the modeling process was trimming the leaves (or terminal nodes) to produce a model of sufficient generality and understandability. Recursive-partitioning algorithms allocate each occurrence to a terminal node. While this procedure can fit multimodal distributions, it can also lead to an overspecified model. Model refinement through leaf-trimming enables subjective ecological understanding to enhance the transparency and robustness of the model.

The models have frequently included temperature variability. The interannual variability (as CV%) of spring maximum and fall minimum temperatures enters into many of the models. This result is not surprising, given that reptiles and amphibians are ectotherms. Surficial soil texture, land cover, and proximity to streams are also important components of habitat. Elevation was found to be significant only for some snake species, and the number of frost-free days failed to provide any explanatory power. The models are undergoing expert review. Accuracy assessment will be conducted using other sources of occurrence data, including voucher specimens from other museums, data from theses and dissertations, species lists from natural areas, and county dot maps. Given the assumptions in the modeling methodology, we expect high but defensible rates of commission error and significantly lower rates of omission error.

These wildlife-habitat relationship models provide an objective framework from which to predict range distributions. They also provide a means through which to assess the gaps in knowledge about species habitat requirements, tolerances, and limits. Future work in modeling species occurrences and predicting range distributions must integrate the temporal dimension into geospatial data, but there are significant challenges in this task (Henebry and Merchant 2001).

Predicting species occurrences needs to be an iterative process that is performed periodically as new data, management tools, and policy objectives become available.

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Assessing the Accuracy of GAP Analysis Predicted Distributions of Idaho Amphibians and Reptiles

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Introduction

The goal of this project was to evaluate the accuracy of the second-generation GAP predicted distribution models for Idaho amphibians and reptiles at three spatial scales. We believe that such accuracy assessments are needed to guide appropriate use of the GAP models. Our approach consisted of using intensive herpetological field surveys (conducted for other purposes) to test the amphibian and reptile models at three different spatial scales.

GAP Models

The second-generation predicted distribution models for Idaho amphibians and reptiles (Scott et al. 2002) consisted of the following elements:

1. EMAP hexagons indicating the potential ranges of the species (i.e., where the models were applied);
2. maps of frost-free days indicating suitable thermal conditions;
3. suitable cover-type maps; and
4. buffered aquatic and wetland features for species such as stream- and pond-breeding amphibians (e.g., tailed frogs and long-toed salamanders) and riparian reptiles (e.g., garter snakes).

Field Surveys

We conducted amphibian and/or reptile surveys in five areas in Idaho (Figure 1). These surveys were conducted for a variety of organizations, including the Bureau of Land Management, Idaho Army National Guard, Idaho Department of Fish and Game, National Park Service, and USDA Forest Service. The study areas ranged in size from approximately 3,600 to 29,000 ha, in elevation from 250 to 2800 m, and included over 500 sampling sites in a wide range of habitats (lava, grasslands, shrublands, forests, riparian, and wetland areas). Sampling durations varied from one to five field seasons. Amphibian surveys consisted primarily of visual encounter surveys supplemented with listening for calling adults and dip-netting for larvae. Reptile surveys consisted primarily of drift-fence/funnel trap arrays supplemented by visual encounter surveys.

Model Testing

We used field guides (Nussbaum et al. 1983, Stebbins 1985) and information from the Northern Intermountain Herpetological Database (Idaho Museum of Natural History) to generate a liberal list of the potential species for all of the study areas (Table 1). We plotted the survey results for each sampling site on the GAP predicted maps for each species for each study area. We compared the predictions from the GAP maps (one prediction for each potential species for each study area) with the field survey results at three spatial scales: (1) for entire study areas (~3,600 to 29,000 ha); (2)

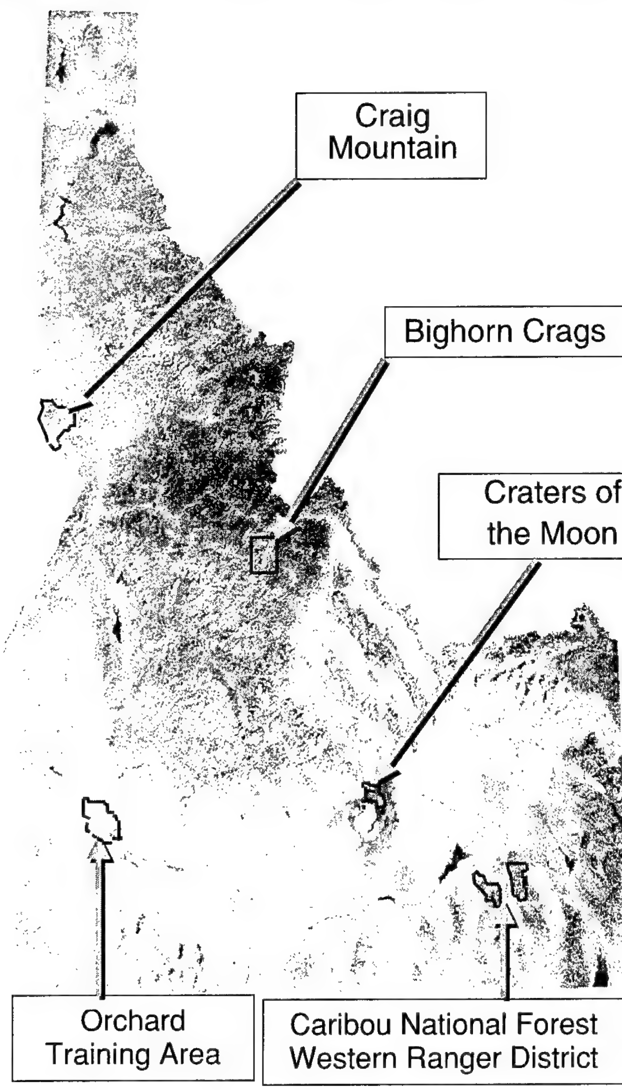

Figure 1. Study area locations.

at sections with sampling sites (259 ha = 1 square mile); and (3) at buffered sampling sites (~2 ha). For each sampling scale/area, we then calculated the number of correct positive predictions, the number of correct negative predictions, the number of incorrect positive predictions, the number of incorrect negative predictions, and overall correct and mistaken classification rates. Classification accuracy equaled the number of correct predictions divided by the total number of predictions.

Results and Discussion

1. Classification accuracy appeared to increase with the size of the sampling area (Figure 2; Karl et al. 2000). The accuracy of the Idaho amphibian and reptile models was relatively high (~85%) at the scale of entire study areas (~3,600 to 29,000 ha; Figure 2 and Table 2). Accuracy decreased substantially (to ~39%) at the fine (2 ha) and intermediate (259 ha) spatial scales sampling areas (Figure 2). Classification accuracy was higher for amphibian species (90%) than for reptile species (81%; Table 2).

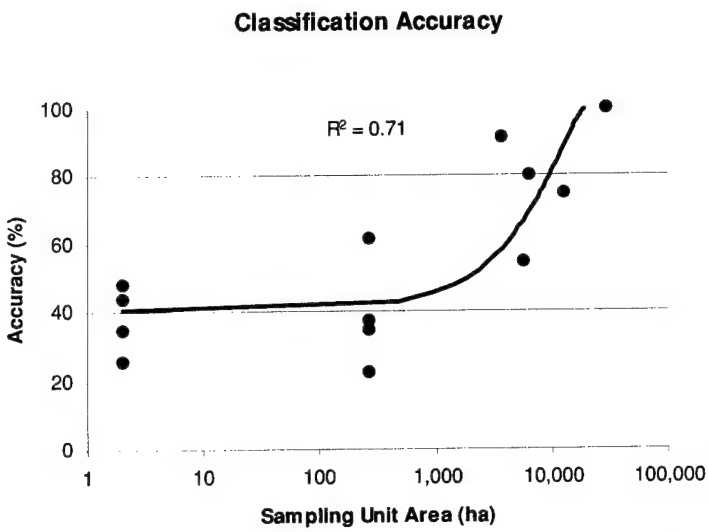

Figure 2. Classification accuracies versus sampling unit areas. Each point represents the overall classification accuracy for all of the sampling sites in each sampling area at the indicated spatial scale. The line for the polynomial regression and the R^2 value are indicated.

2. Classification error rates decreased with increasing size of the sampling area (Figure 3). Few underpredictions (omission errors) occurred. Most of the errors were due to overpredictions (commission errors).

3. In other studies (e.g., Burton 2001), multivariate analyses based on data collected in the field had correct classification percentages at the sampling site (2 ha) scale that were less than 75%. This suggests that high classification accuracies (>80%) for GAP models for Idaho amphibians and reptiles will be difficult or impossible to achieve at fine spatial scales, especially for rare species.

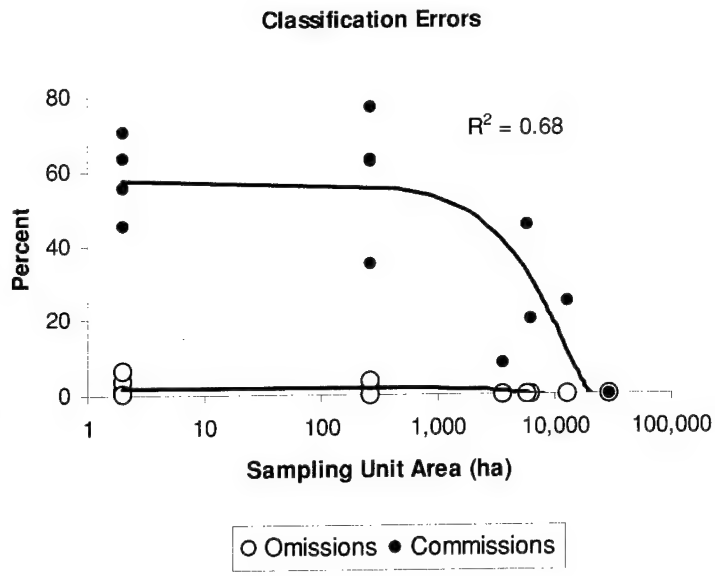

Figure 3. Classification errors versus sampling unit areas. Solid circles indicate commission error percentages for each study area at three different spatial scales. Open circles indicate omission error percentages. The polynomial regression lines and R^2 values are also indicated.

Conclusions

1. Using the Idaho amphibian and reptile GAP models at broad spatial scales should provide an accurate list of probable species for large areas such as national forests. An example of the appropriate use for these models would be the development of a potential species lists for planning an inventory of amphibians and reptiles for a large national park.

2. Using the Idaho amphibian and reptile GAP models at intermediate and fine spatial scales will considerably overestimate where these species occur. Therefore, these models must be used very cautiously when evaluating how well current reserve areas protect a given species. Depending on the size of the reserves, it may require twice as much area to protect species as indicated by gap analysis.

3. Because our field data-based, multivariate models of occurrence for some species have classification accuracies less than 75% at the site scale, we believe that it is unlikely that the current generation of GAP models can achieve high classification accuracies (>80%) at fine spatial scales for most of these species.

Future Research

1. Expand analyses to include more study areas and species (e.g., Clearwater National Forest, Hells Canyon National Recreation Area, and Bear Lake National Wildlife Refuge).

2. Analyze the relationship between biophysical (i.e., temperature and moisture) characterization of study sites and accuracy.

Table 1. GAP model predicted species occurrence by study area. A plus sign indicated that the GAP model predicted that the species would occur; a negative sign indicate a GAP prediction that the species does not occur. No predictions were made for species that were not known to occur.

	Bighorn Crags	Caribou National Forest - Western Ranger District	Craig Mountain	Craters of the Moon National Monument	Orchard Training Area
Long-toed Salamander	+		+		
Tiger Salamander		+	-		
Idaho Giant Salamander			-		
Tailed Frog	+		+		
Western Toad	+	+	+		
Woodhouse's Toad			-		
Great Basin Spadefoot		+	+		
Pacific Tree Frog	+		+		
Boreal Chorus Frog		+			
Bullfrog			+		
Columbia Spotted Frog	+		+		
Northern Leopard Frog		+			
Painted Turtle			-		
Mojave Black-collared Lizard					+
Longnose Leopard Lizard					+
Short-horned Lizard			-	+	+
Desert Horned Lizard					+
Sagebrush Lizard				+	+
Western Fence Lizard			+		+
Side-blotched Lizard					+
Western Skink			+	+	+
Western Whiptail					+
Rubber Boa			+	+	+
Racer			+	+	+
Ringneck Snake			+		
Night Snake			+	+	+
Striped Whipsnake				-	+
Gopher Snake			+	+	+
Longnose Snake					+
Ground Snake					+
Common Garter Snake			+	-	+
Western Terrestrial Garter Snake			+	+	+
Western Rattlesnake			+	+	+

Table 2. Classification accuracies by species for the study area spatial scale.

Species	Number of Study Areas	Correct Postive Predictions	Correct Negative Predictions	Number of Omission Errors	Number of Commission Errors	Classification Accuracy (%)	Probable Causes of Error
Amphibians						90%	
Long-toed Salamander	2	2	0	0	0	100	
Tiger Salamander	2	1	1	0	0	100	
Tailed Frog	2	2	0	0	0	100	
Western Toad	2	2	0	0	0	100	
Great Basin Spadefoot	2	1	0	0	1	50	overpopulation of hexagon map
Boreal Chorus Frog	1	1	0	0	0	100	
Pacific Tree Frog	2	1	0	0	1	50	maximum elevation limit too high
Bullfrog	1	1	0	0	0	100	
Columbia Spotted Frog	2	2	0	0	0	100	
Northern Leopard Frog	1	1	0	0	0	100	
Reptiles						81%	
Mojave Black-collared Lizard	1	0	0	0	1	0	species habitat matrix too general
Longnose Leopard Lizard	2	1	1	0	0	100	
Short-horned Lizard	3	2	0	0	1	67	unexplained population declines
Desert Horned Lizard	1	1	0	0	0	100	
Sagebrush Lizard	2	2	0	0	0	100	
Western Fence Lizard	2	1	0	0	1	50	unknown
Side-blotched Lizard	1	1	0	0	0	100	
Western Skink	3	2	0	0	1	67	species habitat matrix too general
Western Whiptail	1	1	0	0	0	100	
Rubber Boa	3	2	0	0	1	67	incorrect streams / riparian coverage
Racer	3	3	0	0	0	100	
Ringneck Snake	1	1	0	0	0	100	
Night Snake	3	1	0	0	2	33	
Striped Whipsnake	2	1	1	0	0	50	
Gopher Snake	3	3	0	0	0	100	
Ground Snake	1	1	0	0	0	100	
Longnose Snake	1	1	0	0	0	100	
W. Terrestrial Garter Snake	3	2	0	0	1	67	incorrect streams / riparian coverage
Common Garter Snake	3	1	1	0	1	67	incorrect streams / riparian coverage
Western Rattlesnake	3	3	0	0	0	100	

3. Examine spatial variation in the accuracy of the predictions (e.g., the effect of the distance of the closest known record on prediction accuracy). Error rates may be higher at ecoregion boundaries.

4. Use error analyses (e.g., Table 2) to revise GAP models.

5. Develop new modeling approaches that increase classification accuracies at intermediate and fine spatial scales (e.g., incorporation of key habitat features such as communal overwintering sites of snakes).

Acknowledgments

The USGS National Gap Analysis Program provided the funding for analyzing the data. Funding for the field studies was provided by the Aldo Leopold Wilderness Research Institute, Bureau of Land Management, Caribou National Forest, Idaho Department of Fish and Game, Idaho Army National Guard, Idaho State University Graduate Research Committee, National Fish and Wildlife Foundation, National Park Service, The Wilderness Society, and the USGS Biological Resources Division. We would like to thank Nancy Wright, Jason Karl, Leona Svancara, and Mike Scott for assistance with the GAP models. Jason Jolley assisted with the GIS analysis. Leona Svancara and Chris Jenkins reviewed the manuscript.

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APPLICATIONS

Taking Refuge-GAP a Step Further: The GAP Ecosystem Data Explorer Tool in the Roanoke-Tar-Neuse-Cape Fear Ecosystem

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More and more land management agencies and conservation organizations are focusing their efforts on ecosystem conservation. In doing so, they have turned to Geographic Information Systems (GIS) to provide the analytical tools to look at landscape issues. The biological data developed by the Gap Analysis Program (GAP) is an ideal data set for these efforts. It was designed as such. However, the steep learning curve of GIS software and the cumbersome nature of spatial data have severely limited utilization of GAP data, and GIS in general, by the vast majority of people involved with land management. If GAP is to realize its full potential, it must make its data readily available and applicable for use by biologists and land managers not trained in GIS, because that is where the largest impact can be made. In an effort to address that need, the University of Wyoming's Spatial Data and Visualization Center and the National GAP Program developed an ArcView-based decision support tool designed specifically for U.S. Fish and Wildlife Refuge (FWS) managers, called Refuge-GAP (Herdendorf and Crist 1998). While scripting for the tool was not fully developed and was built around Wyoming data, the concept proved attractive to another group of FWS personnel halfway across the continent. Following a presentation of the North Carolina Gap Analysis Project (NC-GAP), biologists from the Roanoke-Tar-Neuse-Cape Fear (RTNCF) Ecosystem Team quickly seized on the idea of implementing GAP data through the use of a decision support tool based on Refuge-GAP. They saw such a tool as not just beneficial to refuge personnel but also to other FWS offices, including Ecological Services and Realty as well as their Ecosystem Planning Office. As a result, the FWS and GAP provided funding to NC-GAP for further development of Refuge-GAP into the RTNCF GAP Ecosystem Data Explorer (GEDE) Tool.

Much like Refuge-GAP, the GEDE Tool is a customized ArcView (ver. 3.2) project that displays and manipulates GAP data through a series of dialog boxes and avenue scripts. The GEDE Tool allows users not savvy in GIS to quickly view data and conduct advanced queries with a few simple clicks. While the GEDE Tool has been designed to be accessible to a broad audience, it is based on a full implementation of ArcView with Spatial Analyst and, thereby, provides an advanced GIS platform for those who wish to expand the complexity of their queries and analyses.

The GEDE Tool begins each session at a common starting point (Figure 1 - see Web version of Bulletin at http://www.gap.uidaho.edu/Bulletins/10). The user can then select an area of interest (AOI) by either importing a coverage or by creating one. Several methods of creating an AOI are presented, including selecting features from standard coverages (e.g., quadrangles, counties, watersheds, refuges, etc.) or by direct on-screen digitizing (Figure 2). Once a user has defined an AOI, the Tool queries the known general ranges, tessellated by the EPA hexagonal grid, of all species to show only those species having a possibility of occurrence within the AOI. The user is then presented with a series of choices designed to narrow the list of species. For example, the user can choose to continue with only federally or state-listed species, high-scoring Partners-In-Flight species, priority species as defined by The Nature Conservancy, species with a user-defined minimum percentage of their predicted distribution on highly protected lands, or any combination thereof. Following that choice, the user is presented with a dialog box listing the selected species present, which allows the user to display either their predicted distribution, known range, or confirmed locations with a single click (Figure 3 - see Web version of Bulletin at http://www.gap.uidaho.edu/Bulletins/10). The user can also display the ownership, management, or protection status of a species' predicted distribution or view a species report, which contains information on taxonomy, habitat preferences, distribution modeling, literature citations as well as a quantitative summary of the areal extent of the predicted distribution by management agency throughout the ecosystem. The user can also choose to calculate a similar summary within just the selected AOI as well as select multiple species to create customized diversity maps.

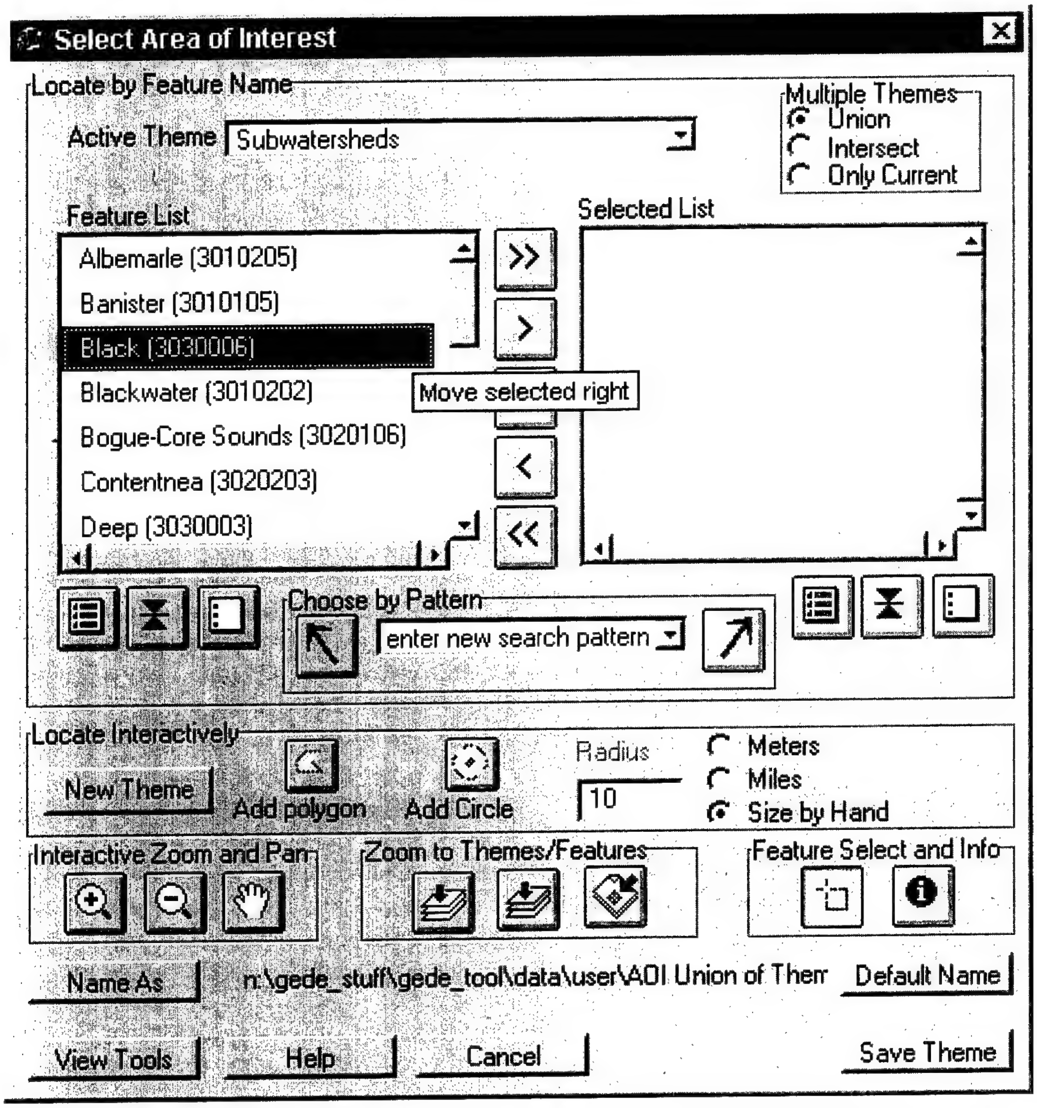

Figure 2. Select Area of Interest Dialog Box. Two methods to select an Area of Interest are presented, including selecting features from coverages and on-screen digitization.

Also built into the GEDE Tool is a spatial representation of the Land Acquisition and Prioritization System (LAPS) employed by the FWS to prioritize lands for acquisition (http://realty.fws.gov/laps.htm). LAPS is designed to be an impartial score of conservation value based on four components: Aquatic and Wetland Resources, Landscape Conservation, Bird Conservation, and Endangered and Threatened Species. While not all scoring criteria used in LAPS are readily transferred to a spatial framework, we identified and created eleven spatial data layers representing various components and subcomponents that can be used as a spatial surrogate for LAPS (Table 1). Once a user selects a Project Area and Landscape Effort polygon, a twelfth layer is created based on areal extent and is summed to the other eleven data layers to create the final LAPS data layer, which is then displayed in the main view along with a dialog box that allows the user to select any of the four component or ten subcomponent data layers for display as well (Figure 4 - see Web version of Bulletin at http://www.gap.uidaho.edu/Bulletins/10).

The RTNCF GEDE Tool is distributed on a 5-CD set containing the customized ArcView project and all associated data necessary for implementation. Centralized scripting architecture (all variables are identified in a single script) and utilization of standardized GAP data format make the GEDE Tool readily applicable with other GAP data sets. You can find more information on the GEDE Tool by visiting the NC-GAP Web site at www.ncgap.ncsu.edu.

The ease of use and accessibility of data make the GEDE Tool valuable to FWS biologists and land managers as they set conservation priorities throughout the ecosystem. With its adaptable nature to other GAP data sets, it should prove a powerful tool beyond the RTNCF Ecosystem as well as beyond the FWS.

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Table 1. LAPS spatial data layers

Component / Sub-component	Data Source	Scoring
Fisheries and Aquatic Resources		
Aquatic Resources Population Information	FWS[1]	Aquatic trust species and state species of concern presence were noted within subwatersheds. Diversity was weighted for a final score for each subwatershed.
Affected Species Information	NOAA[2], FWS/LAPS[3]	Aquatic trust species presence was noted within each major estuary. Diversity was weighted for a final score in each estuary.
Habitat	FWS/LAPS[3]	Free-flowing river reaches > 125 miles and critical or hot-spot watersheds were scored according to LAPS criteria.
Wetland Type	FWS/NWI[4], FWS/LAPS[3]	Wetland types were scored based on LAPS scoring criteria.
Percent Wetland Loss Expressed by Acreage by State	FWS/LAPS[3]	States were scored based on LAPS scoring criteria.
Ecosystem Conservation		
Ecosystem Decline	FWS/LAPS[3], NC-GAP/VA-GAP[5]	Habitat types forming identified ecosystems were scored according to LAPS criteria.
Landscape Conservation	FWS/LAPS[2]	Project polygon was scored based on the Project and Landscape Effort polygon areas (LAPS criteria).
Contributions to National Designations	FWS/LAPS[3], NC-GAP/VA-GAP[7], AUDUBON[8], NAWMPJV[9]	National designations identified by LAPS were scored accordingly.
Endangered and Threatened Species		
	FWS/LAPS[3], NC-GAP/VA-GAP[6]	Scoring based on LAPS Factor A was assessed for each species on their predicted distributions. Other Factors were not scored.
Bird Conservation		
Importance to Specific Species or Populations	FWS/LAPS[3], NC-GAP/VA-GAP[6]	Diversity map of species for which the ecosystem contains 5-50% of their range
Avian Diversity Score	FWS/LAPS[3], NC-GAP/VA-GAP[6]	Diversity map of species on the Regional lists; Nongame Species of Management Concern, NAWCA Priority Waterfowl Species and Species of Regional Concern

[1]Laney, 2001
[2]Nelson et al., 1991
[3]USFWS, 2000
[4]USFWS, National Wetlands Inventory Data, http://www.nwi.fws.gov
[5]NC-GAP & VA-GAP, Land Cover Data
[6]NC-GAP & VA-GAP, Vertebrate Species Predicted Distribution Data
[7]NC-GAP & VA-GAP, Stewardship Data
[8]Audubon Society, Important Bird Areas, http://www.audubon.org/bird/iba/index.html
[9]North American Waterfowl Management Plan Joint Venture

Barriers to Use of the GAP Database by Local and Regional Land Use Planners in New Mexico

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Introduction

This project builds on a growing body of research, beginning with the New Mexico Gap Analysis Project (NM-GAP) in 1996 (Thompson et al. 1996) and resulting in publication of an assessment of gap analysis data by the New Mexico Cooperative Fish and Wildlife Research Unit (Deitner et al. 1999). Employing data from interviews with planning and development officials in 25 organizations across New Mexico, we explore whether and how they use data from NM-GAP. Specifically, we examine the extent of use of GAP materials and identify barriers to the use of GAP data in decision-making processes.

Methodology

Twenty-five officials were interviewed from ten counties, seven Indian nations, and eight regional development organizations (RDOs). The 25 organizations reflect one potential client group that may benefit from GAP data. We designed an open-ended interview guide to learn (a) how planning decisions are made and (b) the extent to which local governments use NM-GAP data. Interviews were transcribed from tape recordings and supplemented by field notes. Content analysis was employed because it aids in identification of patterns in question responses and provides researchers the flexibility to incorporate information that emerges during the interview process (Feldman 1995; Miles and Huberman 1994).

Discussion of the Findings

The level of use of the NM-GAP data by local governments is low; 16 of the 25 jurisdictions were not even aware of it. Only two, both regional planning agencies, used the database. The Council of Governments (COG) that serves the Albuquerque metropolitan area was the only organization to use the GAP database to any significant extent. However, a planning specialist familiar with the COG contends that the RDO actually "did little with GAP data" (Czerniak 2001). The only other agency using GAP materials was the South Central COG, where the official interviewed explained that he was using the GAP database only "sporadically or spasmodically."

Initially, we thought that this meant that more work had to be done to publicize the availability of GAP data to local planners. However, in reviewing the interviews it is clear that low awareness is only one obstacle to the use of GAP in local planning decisions. Two major underlying issues emerged that would limit the influence of the NM-GAP data in local planning. First, planning officials have little influence on planning decisions. Second, economic not environmental factors are most important in planning decisions.

The planning officials we interviewed exerted varying degrees of influence in the policy-making process. In general, staff might make recommendations regarding planning and development to elected or appointed officials, but their primary function is to provide technical assistance to decision makers. Of the three types of organizations interviewed, planning was seen as important in only the RDOs. However, these regionwide planning organizations exerted the least influence in policy making due to their limited role. In contrast, none of the counties or tribes identified planning as a priority.

The theme that planning was not a priority emerged again when we asked about the amount of support that planning departments received from political leadership. Fourteen of the 25 officials (56%) had leadership support. However, support was most likely to be found in the RDOs where three quarters reported support. As mentioned above, these organizations are the furthest from the actual decision-making process. Among county and tribal planners, less than half felt they had the support of political leadership. Support from leadership was lowest among tribal planners, where only about a quarter said they had the support of leadership. Lack of support was most likely where there was a conflict in the goals of professional staff and traditional leaders.

For those officials who reported little support for planning, the quality or usefulness of GAP would be irrelevant. Without support of decision makers, information and technology provided for land use planning by GAP are wasted.

The second problem facing the use of GAP as a tool for environmental planning is that environmental values are not important in the decision-making process of most local governments in New Mexico. While 16 of the 25 officials cited economic development as a priority, only nine cited the environment. As a priority, the environment ranked behind the economy, human services, client services, and infrastructure. Since almost two-thirds of the officials did not identify the environment as an organizational priority, it is difficult to see what use their agencies could have for the GAP database.

While the impact of land uses on the environment was not often a priority, it was a factor considered by most of the agencies. However, the environmental factors considered were driven by practical rather than aesthetic considerations. Issues raised included the community's need for pure drinking water, sewage systems, agricultural land for farming, logging, and wildlife management for economy-related hunting and fishing. In the majority of these cases, preservation of the environment was less the objective than was the management of natural resources for human consumption.

Conclusions and Observations

The major barrier to local agencies using NM-GAP data is that they are not aware of them. Other barriers include inadequate infrastructure, such as outdated or incompatible computer equipment and lack of access to the Internet, insufficient expertise or personnel to operate a GIS system, and insufficient knowledge of how to apply GAP data to local problems. While it may be possible to overcome these technical barriers, it is unlikely that the database will have much effect on local land use planning in New Mexico.

Support for planning among political leaders is weak. In many cases, decision makers have chosen not to do planning and not to regulate land use. The elected or appointed officials who make the actual land use decisions may take little notice of the recommendations made by their staffs. Our research shows that whether or not GAP data are used depends on the decisions made by the political leaders, who are more affected by interest group pressure than planning department recommendations.

Another problem is that the GAP database reflects priorities that are different from those of most decision makers. These leaders are less concerned with environmental values than they are with economic development. Further, the environmental issues of most concern to officials, such as clean water and waste disposal, are not in the GAP domain of biodiversity conservation.

While this research raises many questions, one thing is clear: simply providing planners with a new tool does not assure that it will be used. Until the information is genuinely used by those with power in the decision-making process, and until the values addressed by the GAP program are seen as at least as important as economic concerns, the NM-GAP project will have little influence on planning decisions.

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Biodiversity Predictions: Integrating Urban Growth Models with Land Cover Data and Species Habitat Information

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Introduction

Habitat loss and subsequent fragmentation due to urban development are part of a larger suite of anthropogenic impacts on biodiversity, but they now rank among the principal causes of species endangerment in the United States. Several types of urban growth simulation models have been developed which can supply useful information for biodiversity planning. In many cases, however, the data required for biodiversity planning may not be compatible with the urban models, leading to analytical inaccuracies and misleading conclusions. Here, I briefly introduce a case study for biodiversity analysis and examine several lines of logic likely to be employed in such assessments. I conclude with a discussion of assumptions built into the data and their influence on model outcome.

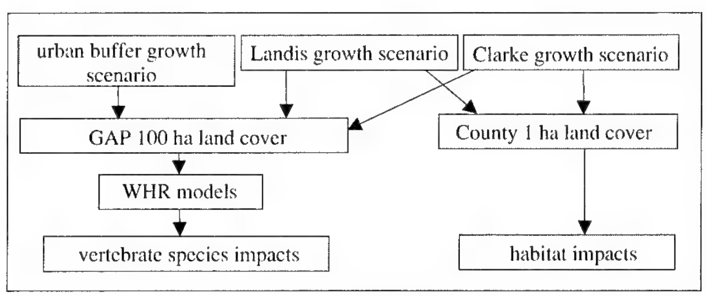

Figure 1. Flow chart for biodiversity sensitivity analysis. Three urban growth scenarios and two land cover models combine to evaluate vertebrate and habitat impacts in Santa Cruz County, California.

Techniques for Model Integration

Habitat quality and quantity aspects of biodiversity were examined using three principal inputs: urbanization scenarios, wildlife habitat maps, and species habitat models. Output from the analyses was reported as loss of habitat area or, in some cases, in terms of impact to the vertebrate species associated with degraded habitats.

A flow chart of the models and analyses provides an overview of the biodiversity sensitivity analysis (Figure 1). Three different models for predicting patterns of urban expansion were tested. These included the 500-meter "urban buffer," "Landis" (Landis and Zhang 1998), and "Clarke" (Clarke and Gaydos 1998) scenarios. Outputs from the different growth models were then used in conjunction with coarse-grain (100 ha minimum mapping unit) land cover maps from the California Gap Analysis Project (GAP, Davis et al. 1998).

The Landis and Clarke models were also used with a finer-grain (1 ha) land cover data set. This map layer was commissioned by the Association of Monterey Bay Area Governments (AMBAG) based on 30-meter Landsat Thematic Mapper (TM) imagery. Spatial distributions of individual vertebrate species predicted to occur in the study area were made possible by applying wildlife habitat relationship (WHR) models (Airola 1988) to the coarser-grained GAP land cover data. Potential impacts of urban growth to these species were explored by intersecting scenarios of future urban growth from each of the three models with the WHR-based predicted distributions of the species (e.g., Figure 2).

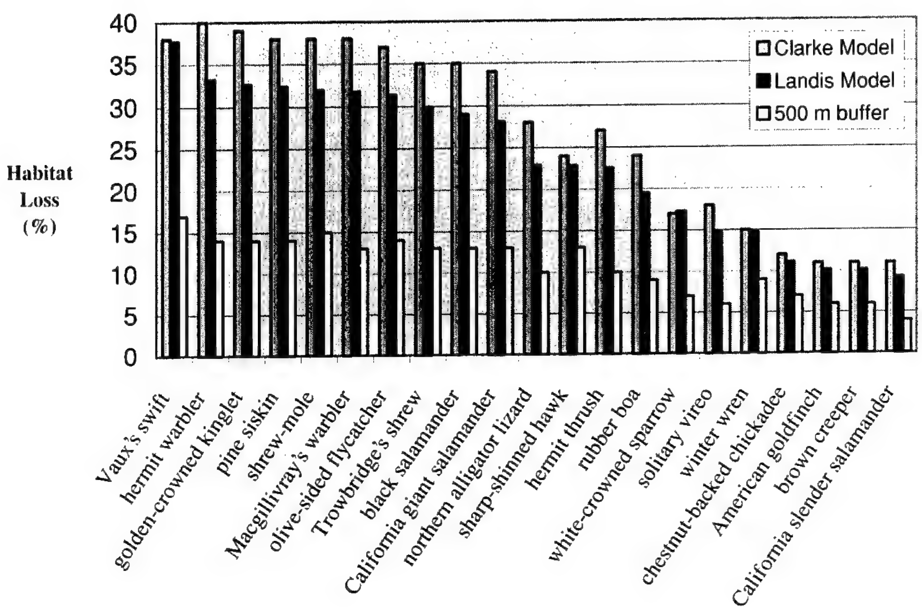

Figure 2. Comparison of predicted habitat loss under three growth scenarios in Santa Cruz County, California: 500-meter urban buffer, Landis growth model, and Clarke growth model. Species and habitat data are from the California Gap Analysis Project (GAP). Habitat classes are rank-ordered based on the results from the Landis model.

Discussion

The species habitat analysis outlined here is a close examination of one major factor in the assessment of biodiversity. Other biodiversity elements such as ecoregional analysis, restoration potential, special features, and habitat shape are also important (Cogan 2002), though these were not specifically addressed in this study. The combination of urban growth models and land cover maps (Figure 1) was used to compare measures of habitat and vertebrate impacts. Here, habitat impacts were considered to be actual habitat areas converted to urban land use. For example, if a 1,000 ha forest is reduced to 900 ha after urbanization, the habitat loss is 10%. If the same forest is reassessed in terms of native vertebrate habitat, it may be more important to consider buffer distances from impacts, non-linear predation effects, and other complex landscape metrics. These more specific approaches can be valuable in some instances; however, when applied to a regional study with many species, the results can be misleading. Stated differently, it is challenging to model disturbance effects as realistically as possible while working with a group of dissimilar species over a broad area.

The approach to vertebrate habitat assessment presented here assumed that if a highly intrusive land use such as urbanization entered a habitat patch, then the entire patch was likely to be compromised in terms of habitat quality for vertebrate species. In some instances, this assumption may have overemphasized the impact of urbanization. On the other hand, it was also likely that urbanization effects were underemphasized in cases where urban expansion approached (but not actually entered) a habitat area. An alternate model could employ spatial buffers to model the neighborhood effects of urbanization; however, this approach would introduce additional complexities, such as splitting map polygons, and imposes the need for species-specific analysis. Both the habitat and species types of impacts are important; however, it is necessary to clarify the conceptual differences between habitat and vertebrate impacts when evaluating or discussing urban growth impacts. The methods used in this analysis were based upon an underlying logical sequence most simply presented as a flow chart (Figure 3). A central assumption here was that different urban growth patterns should have measurably different biodiversity impacts. As with any metamodel, it was also important to ensure that the data and various component models were compatible for integrated analysis. It is often illuminating to investigate where the logic of a scientific investigation might become unsound, as well as where it is strong. The logical flowchart outlines key junctions

where this type of biodiversity assessment might face impediments and offers explanations and recommendations for each situation.

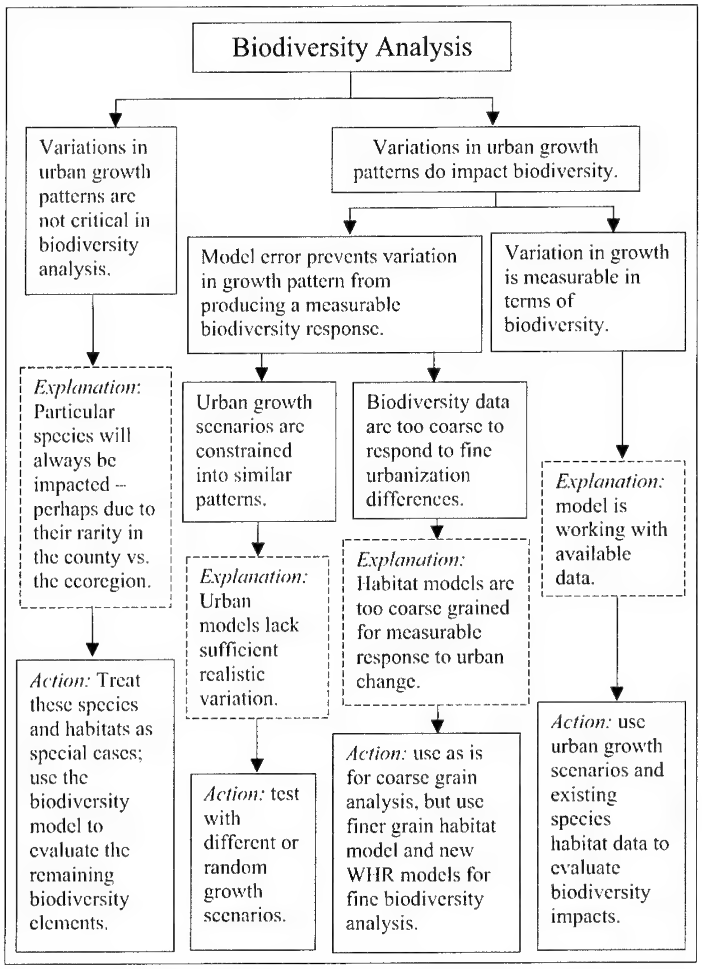

Figure 3. Logical flow chart for biodiversity analysis with urban growth models.

Given perfectly accurate biodiversity and urban growth models, lack of biodiversity response will still occur if the two models are not spatially or thematically compatible. An indicator of this type of incompatibility can be seen in the comparison of vertebrate habitat losses following different urbanization scenarios (Figure 2). One interpretation of this result suggests that vertebrate impacts are much the same following either the Clarke or the Landis models. Indeed, it seems remarkable that the *rank order* of species and even habitat impacts is so similar under two independent and seemingly different growth models. It would seem to require a radically different growth model like the simplistic 500-meter buffer to produce a significantly different outcome. Another, perhaps more likely, interpretation is also possible. If the GAP data on wildlife habitat relationships are spatially coarser that the growth models, our ability to differentiate between the Landis and Clarke models will be diminished. In support of this hypothesis, the appearance of the map products and (most importantly) the habitat impacts, indicated substantial differences between each of the three urban models.

The balance of spatial grain and thematic detail is an important consideration when producing and using maps of land cover for use in biodiversity analysis. Using the AMBAG 30-meter MMU land cover map, the fine map grain results in relatively large areas (up to 49,000 ha) to be mapped as contiguous albeit marginally connected patches. At slightly coarser map grains, many of the corridors of connecting habitat would merge into other classes, resulting in a very different data set for the habitat modeler. This example illustrates how fine-grain maps with coarse thematic detail can overemphasize habitat connectivity. In this case, the assumption that urban disturbance on the edge of a habitat patch impacts the entire patch becomes tenuous when using data with fine spatial grain but coarse thematic grain such as the AMBAG 30-meter land cover map. As 100-meter or finer-grain urban growth models gain acceptance as a reasonable spatial scale to model the biodiversity land use complex, more research is needed to ascertain the appropriate levels of thematic resolution in land use and land cover mapping.

There are several difficulties associated with measuring regional urban impacts on vertebrate species. The model presented here used polygons of habitat to represent potential distributions of vertebrate species and assumed that analysis of divided polygons was not a valid application of the data. Detailed studies of specific divided habitat polygons are possible, given appropriate species-specific data. However, this local approach will not be effective regionally. Urban development is sometimes seen as a continuous creeping of small steps, whereby each development project in isolation is difficult to assess for regional biodiversity impact. The species assessment method presented here used habitat polygons to model impacts, effectively dealing with the "urban creep" issue while maintaining biologically meaningful area units. The complementary combination of a discrete species metric (e.g., polygon-based) along with a continuous habitat model is a powerful and much needed approach.

As biodiversity models such as those discussed here evolve and build in complexity, our land cover maps and wildlife habitat relationship models will be pressed to deliver more information with higher quality standards. Some of our data sources have already evolved from simple maps of predicted species location to become temporally dynamic models of predicted species connectivity and spatial pattern. Unfortunately, most of our current maps are not up to this advanced standard. Like most modelers, cartographers have long known that the design constraints of producing the best habitat maps will depend on the specific questions being asked of the data. This fundamental principle is sometimes obscured or overlooked when we allow technological capabilities such as satellite sensor resolution and radiometric spectral response to overly influence our understanding of habitat classification and vertebrate distribution.

These findings were presented to facilitate an improved understanding of habitat and species impact models and to provide direction

for future land use and land cover mapping. The specific models discussed here are important elements of more generalized biodiversity assessments, which are continually improving our understanding of biodiversity and promise to provide additional guidance to minimize the disruptive impacts of urbanization and development.

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A Method to Assess Risk of Habitat Loss to Development: A Colorado Case Study

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Introduction

Land use planning for private land is fundamentally important for conserving biodiversity nationwide (Dale et al. 2000). A major opportunity to refine the Gap Analysis methodology is to integrate socioeconomic factors to better assess both levels of protection and risk, particularly on private lands (McKendry and Machlis 1993). Incorporating information about private lands into the GAP methodology is important because private lands contain disproportionately high levels of biodiversity and habitat for rare species (Bean and Wilcove 1997); many of the important causes of habitat loss and habitat fragmentation stem from changes of land use on private lands; and they vary greatly in the degree of human-induced impacts on habitat.

GAP methodology identifies land cover types and species distributions that may be particularly vulnerable given their status in the current array of land ownership and management. However, a main drawback is that the coarse categories (4) of biodiversity management status, based on potential land use activities, may be weakly associated with actual species vulnerability (Stoms 2000). Some types of human activities cover broad expanses of the landscape and result in substantial land cover conversion, such as mono-crop agriculture and urban uses, and these activities typically are well-represented on land cover maps. However, land cover maps miss vast areas under the influence of either broad-extent, low-intensity land uses (e.g., low-density rural residential development) or small-extent, high-intensity activities such as oil and gas wells. Compiling data that more directly relate impacts on biodiversity associated with land uses is challenging (Stoms 2000), but offers a straightforward and reasonable means to identify threats to biodiversity, although actually demonstrating species responses to land use activities is quite challenging in practice (Theobald et al. 1997).

Another opportunity to refine status categories is to move beyond vulnerability and differentiate areas on the landscape (and species habitat) that are currently threatened or likely to be threatened in the future by land use activities associated with human development (e.g., urbanization, intensive agricultural practices, logging, etc.). Without considering these threats to species and habitat, conservation resources overall may not be properly prioritized (Cassidy et al. 2001) to achieve the greatest benefit for the most species (Scott et al. 1993). McKendry and Machlis (1993) described a general framework to extend biodiversity gap analysis by including socioeconomic indicators such as population change, economic trends, government policies, and land use conversion. Although current GAP methodology recognizes this limitation–for example, "We emphasize, however, that GAP only identifies private land as a single homogeneous category and does not differentiate individual private land units or owners…" (Csuti and Crist 2000)–few methods to address these limitations exist.

Recently, Stoms (2000) compared three indicators of development–permitted land use, "roadedness," and human population growth–to stewardship status for two pilot areas in California and found large differences between the more direct indicators and the general proxy of status or protection level. Theobald et al. (1998) de-

veloped a preliminary assessment methodology to examine the impacts of private land development on habitat using GAP land cover data, but did not quantify differences between management protection level and other indicators of land use.

Here we present an approach to refine the identification of vulnerable areas to consider what lands are threatened by various human land uses, especially those that have significant impacts and are increasing rapidly, such as urbanization and rural residential development. We utilized data readily available nationwide to develop a methodology to incorporate information about land use on private lands when assessing protection levels on private (and adjacent public) lands, and to forecast future levels of development to identify areas that are most at risk from potential private land development. We illustrate this approach using a case study from Colorado.

Colorado, often referred to as the "bellwether" of the Rocky Mountain West, has seen significant threat to habitat due to development pressures. Indeed, not only is the West's population growing three times as fast as the rest of the US (US Census Bureau 2001; Baron et al. 2000), but demographic and economic trends are changing the pattern and location of development (Riebsame et al. 1997). As a result, more than 60% of the West's counties are experiencing "rural sprawl," where rural areas (outside of city and town limits) are growing at a faster rate than urban areas (US Census Bureau 2001). In Colorado, population growth rates in nearly one-fifth of the counties exceeded 5% from 1990 to 1997, and this growth has caused large expanses of low-density development (Theobald 2000).

Methods

We developed two easily mapped measures of development and then used these indicators to assess which land cover types were particularly at risk and to identify where habitat is threatened by development. Our case-study assessment utilized both the land stewardship map and the species distribution maps produced by the Colorado Gap Analysis Project (Schrupp et al. 2001).

We selected two socioeconomic indicators to develop maps for and to test in relation to biodiversity: roads and housing density. The effects of roads on biodiversity and ecological integrity has been well documented (Forman and Alexander 1998). Road and housing density are often thought to be highly correlated, but because mixed results were obtained for a preliminary analysis (Theobald 1997), we chose to model both indicators to further test whether these were highly correlated for statewide areas. Although population density is often used to map human activity patterns, population data is tied to the primary place of residence and so underestimates potential effects on habitat in areas with a high percentage of second and vacation homes (Theobald 2000; Theobald *in press*). Moreover, potential impacts to habitat such as removal of native vegetation, alteration of vegetation structure for defensible space for wildfire protection, and introduction of exotic species are more closely related to housing density.

Although road density is typically used as a measure of road effects on biodiversity, we created a "roadedness" map (Figure 1) following the methodology developed in California (Davis et al. 1996; Stoms 2000). Roadedness does not suffer from bias introduced when calculating road density in areas where many roads close together result in very high road densities and better accounts for spatial pattern. Moreover, an important assumption in creating a map that depicts effects of roads on biodiversity is that larger roads (e.g., highways) typically affect species further from the road than smaller (e.g., local) roads, because larger roads are typically wider and carry more traffic. Therefore, the "roadedness" index estimates the proportion of an area (e.g., watershed, county, status category) that is affected by roads. Roads from US Census Bureau TIGER files were converted to 30 m GRIDs and then were assigned a buffer width according to the schedule in Table 1.

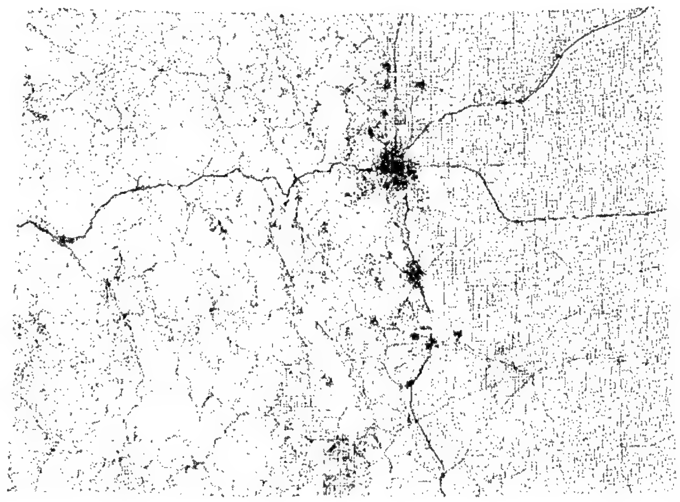

Figure 1. Roaded areas in Colorado.

To map historical and current housing density, we used 1990 US Census Bureau block-groups and blocks, which are subdivisions of the familiar census tract. To account for underestimation of units in previous decades, decennial estimates for 1940-1980 were corrected using a correction factor computed as the ratio of number of units in a county from historical census divided by total housing units summed from current estimates (Theobald 2001b). To map likely future housing density, we developed a model that recognizes and represents land use changes beyond the urban fringe (Figure 2). Although a number of approaches have been developed to forecast future growth patterns, most efforts have focused on *urban* growth and changes to urban or built-up cover types and are based on land cover types classified from satellite imagery and occasionally from high-altitude aerial photography (e.g., Brown et al. 2000). Recently, Clarke and Gaydos (1998) developed a California-based model to predict urban growth in San Francisco and Baltimore. Stoms (2000) distributed population growth using a rule-based approach that arbitrarily limited growth to 8 km expansion from urban cores.

Table 1. Roadedness index buffer widths. Total width of affected roaded portion is twice buffer width. After Davis et al. (1996) and Stoms (2000).

Census Feature Class Code	*Description*	*Road class*	*Buffer width(m)*	*Total width (actual)*	*Expand cells (30 m cell size)*
A10-A18	Primary (limited access or interstate highway)	1	500	1000 (990)	16
A20-A28	Primary (other US or State highway)	2	250	500 (510)	8
A30-A38	Secondary (state and county)	3	100	200 (210)	3
A40-A48	Local	4	100	200 (210)	3
A50-A58	Vehicular (4WD)	5	25	30	0
A70-A73	Other (hiking)	9	0	0	0

Rather than rely on urban-centric models of housing growth, we used county-based population projections to derive the number of housing units needed in 2025 and 2050 (Theobald 2001a). We then spread these units throughout the block-groups by assuming that a block-group's density could not exceed the average housing density of its neighbors, for each decadal time step (Theobald et al. 2001).

We then analyzed the threats to habitat by overlaying the roadedness and housing density layers with land cover data.

Results

Over 269,000 kilometers (~167,000 miles) of roads were mapped in Colorado, resulting in 21.7% of Colorado being "roaded." Roaded proportion varies widely by watershed, from a low of 6.1% to a high of 40.9% (mean of 20.7%) (see Figure 3).

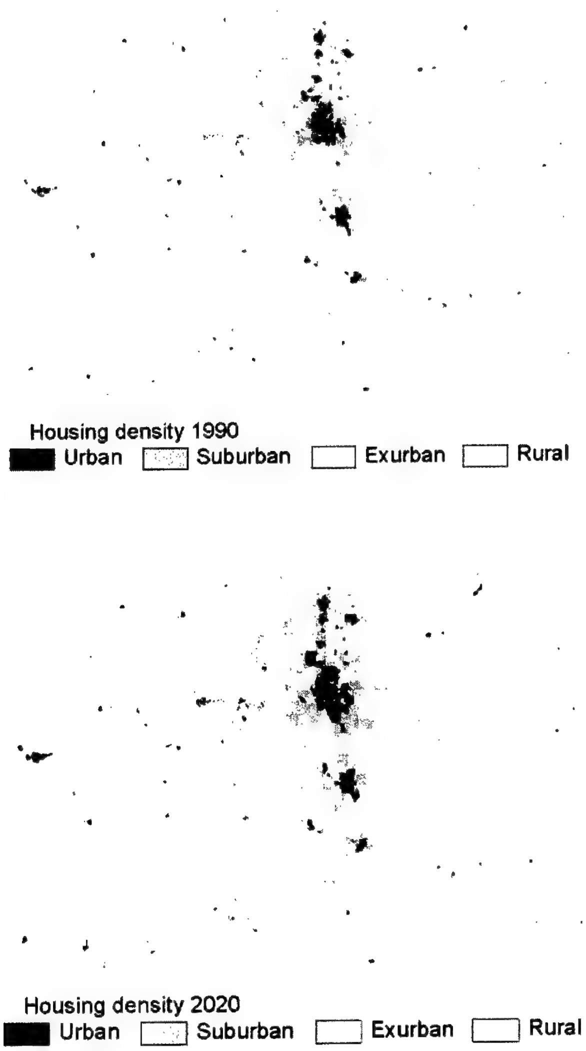

Figure 2. Housing density in 1990 and 2020.

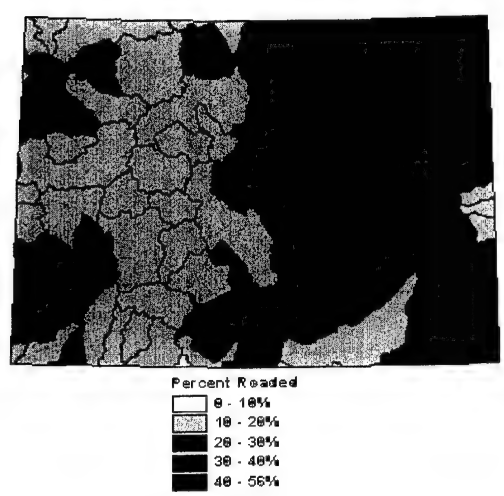

Figure 3. Percent roaded by watershed.

Contrary to common belief, there was a poor relationship (R^2 = 0.21) between percent roaded and the proportion of public land in each county. Although 10% of Colorado was "protected" (Status 1 and 2), about 13.5% of these protected areas were roaded. Conversely, the majority of Colorado was "unprotected" (Status 4), yet only about one-quarter of this area was roaded. About 5.1% of Colorado was developed in 1990 at densities higher than rural (i.e. urban, suburban, and exurban areas), and an additional 5% of Colorado will be "at risk" from new development forecasted for 2020, located mostly along the foothills of the Front Range and mountain valleys.

In Colorado, 24 of 43 natural land cover types were found to be *vulnerable*, which we define here as less than 10% protected in Status 1 and 2 (see Table 2). We designated a land cover class as *threatened* if 20% or more was roaded, or if 15% or more coincided with exurban or greater density development in 1990, was within 2 km of exurban or greater development in 1990, or coincided with areas at risk of development by 2020. Most vulnerable land cover

Table 2. Statistics for proportion of protected, roaded, and developed for each land cover type in Colorado. Grey areas denote native land cover types that are 10% protected (Status 1 and 2), threatened by roads (>20%), or threatened by development (>15%).

*Land Cover (*human-made)*	*Class*	*Hectares*	*% of State*	*% Protected*	*% Roaded*	*% Developed % in 1990*	*% w/in 1 km of developed*	*% w/in 2 km developed*	*% at risk of dev. in 2020*
Urban or built-up lands*	11001	217,270	0.81	0.19	84.44	88.4	95.3	97.2	13.4
Dryland crops*	21001	3,688,283	13.70	0.07	23.71	2.7	5.0	7.7	2.7
Irrigated crops*	21002	1,900,710	7.06	0.01	37.32	18.8	27.5	34.7	11.9
Orchards*	21003	222	0.00	0.00	29.73	98.7	100.0	100.0	80.6
Confined livestock feeding*	21004	458	0.00	0.00	45.41	48.7	48.7	48.7	-
Tallgrass prairie	31010	202,424	0.75	0.04	25.28	12.9	17.5	20.6	22.0
Sand dune grassland	31013	53,769	0.20	0.00	14.70	0.0	0.0	0.0	-
Midgrass prairie	31020	494,915	1.84	0.31	24.36	9.1	14.5	20.3	10.2
Shortgrass prairie	31030	4,029,190	14.96	0.19	23.14	1.1	2.7	4.4	1.2
Foothills/mountain grassland	31040	670,771	2.49	2.30	29.24	8.3	13.5	17.4	16.2
Mesic upland shrub	32001	116,051	0.43	3.26	22.86	11.8	21.3	27.0	11.1
Xeric upland shrub	32002	58,418	0.22	4.61	29.97	28.1	41.4	47.9	19.2
Gambel oak	32003	849,092	3.15	4.85	19.58	3.7	7.7	10.9	8.7
Bitterbrush shrub	32005	74,020	0.27	1.67	26.97	0.0	0.0	0.0	0.1
Mountain big sagebrush	32006	94,409	0.35	19.05	15.65	0.4	3.2	6.3	0.2
Wyoming big sagebrush	32007	44,364	0.16	0.00	24.03	0.0	0.0	0.1	-
Big sagebrush	32009	1,679,838	6.24	3.49	26.66	2.2	5.0	7.5	4.3
Desert shrub	32010	432,350	1.61	1.48	27.87	1.5	3.9	7.7	3.7
Saltbush shrub	32011	484,020	1.80	2.01	19.68	2.5	6.5	10.1	3.5
Greasewood fans and flats	32012	219,860	0.82	4.83	23.25	2.2	3.5	5.0	0.1
Sand dune shrub	32013	1,080,718	4.01	0.45	23.21	0.4	1.4	2.8	0.8
Disturbed shrub	32030	1,174	0.00	0.00	47.79	-	0.0	0.0	-
Aspen	41001	1,266,099	4.70	21.99	11.60	2.1	8.2	13.0	3.1
Spruce/fir	42001	1,871,967	6.95	46.53	9.14	1.5	9.5	16.8	1.6
Spruce/fir clearcut*	42002	9,200	0.03	8.38	29.68	0.0	0.0	0.0	-
Douglas fir	42003	432,356	1.61	14.13	14.69	7.1	24.1	34.3	7.0
Lodgepole pine	42004	872,309	3.24	34.44	15.31	6.6	16.0	20.9	4.1
Lodgepole pine clearcut*	42007	16,245	0.06	5.74	26.51	0.3	3.7	3.8	-
Limber pine	42009	1,227	0.00	0.08	18.34	0.0	0.0	0.4	-
Ponderosa pine	42010	1,388,349	5.16	12.68	20.96	13.7	28.2	34.8	10.7
Blue spruce	42011	2,940	0.01	46.53	2.79	0.0	0.0	0.0	-
White fir	42012	4,012	0.01	0.00	26.99	0.0	0.0	0.0	-
Juniper woodland	42015	466,417	1.73	12.16	15.34	0.3	1.2	2.7	1.4
Pinyon juniper	42016	2,503,871	9.30	7.24	17.93	1.9	6.4	9.9	4.2
Bristlecone pine	42017	22,813	0.08	10.31	28.85	14.8	30.4	38.0	26.5
Mixed conifer	42018	183,212	0.68	24.19	15.11	2.1	7.9	13.5	0.3
Mixed forest	43000	83,117	0.31	16.25	15.70	0.8	4.8	7.9	1.7
Open water	52001	90,794	0.34	13.47	16.69	6.4	28.1	37.0	3.9
Forest dominated wetland/riparian	61001	114,414	0.42	9.16	27.79	11.5	27.2	33.9	6.8
Shrub dominated wetland/riparian	62001	52,217	0.19	13.77	21.38	5.3	10.2	13.1	3.5
Graminoid and forb dominated wetlands	62002	45,468	0.17	6.70	27.87	2.9	7.6	10.5	6.3
Barren lands	70000	16,950	0.06	1.74	56.45	54.4	72.2	83.2	40.7
Unvegetated playa	71001	388	0.00	0.00	8.76	0.0	0.0	0.0	-
Sandy areas other than beaches	73000	18,054	0.07	0.00	13.98	0.6	1.4	2.8	-
Exposed rock*	74001	46,072	0.17	50.78	4.22	1.0	6.4	10.8	1.2
Mining operations*	75001	6,916	0.03	1.13	8.66	24.7	41.8	49.7	23.9
Prostrate shrub and tundra	81001	127,132	0.47	74.53	44.66	1.5	9.2	15.9	1.9
Meadow tundra	82001	183,496	0.68	62.92	2.64	1.8	16.6	27.9	1.0
Subalpine meadow	82002	204,731	0.76	28.28	4.50	4.8	14.1	21.3	3.8
Bare ground tundra	83000	200,106	0.74	81.59	18.33	2.1	13.1	21.3	2.0
Mixed tundra	85000	299,941	1.11	66.47	0.92	1.3	13.2	22.5	2.9

types were also threatened by roads, although ponderosa pine, bristlecone pine, shrub-dominated wetland, and prostrate shrub/tundra were identified as threatened but were not identified as vulnerable. Tallgrass prairie, foothills/mountain grasslands, and bristlecone pine were identified as threatened by future development in 2020. Moreover, a number of land cover types proximal to development were found to be threatened, but were not identified as vulnerable, most notably water, spruce/fir, Douglas fir, ponderosa pine, bristlecone pine, forest-dominated wetland, and most tundra cover types.

Conclusion

Incorporating socioeconomic factors, such as road and housing density, provides an important opportunity to extend the methodology of gap analysis. We found that both road and housing density were useful indicators of potential impacts from activities associated with human land use and could be used to refine analyses of vulnerability to include level of threat (Figure 4). The data to produce these layers were readily available, and methods to convert them into reasonable indicators were straightforward. (Note: The derived maps of housing density are available at http://www.ndis.nrel.colostate.edu/davet/dev_patterns.htm).

In addition to roads and residential land use, there are a number of additional land uses associated with humans that would be useful but are more challenging to incorporate. For example, additional data and methodologies are needed to better incorporate knowledge about the possible effects of grazing, logging, oil and gas wells, and fire suppression in spatially-explicit models of effects.

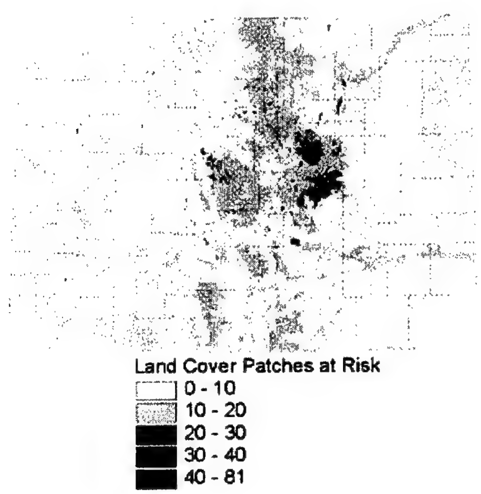

Figure 4. Patches of land cover ranked by percent "at risk" from development to 2020.

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Planting Seeds for Conservation Planning in Tennessee

Marty Marina
Tennessee Conservation League, Nashville

Coincidental with the Tennessee Wildlife Resource Agency's (TWRA) and Tennessee Technological University's (TTU) work to develop and depict GAP data, the Tennessee Conservation League (TCL)—a not-for-profit education organization—began working with state leaders in an effort to make high-quality, user-friendly GIS data available to state and local planners. A variety of strategies were employed and, while the results have been slow to materialize, seeds sown in USGS/GAP-funded projects are now producing results. Let me explain where we began, to help you understand how far Tennessee has come.

A series of meetings with state agencies in 1996 indicated that many were unwilling or unable to contribute to a comprehensive effort to layer land use, land cover, and animal distribution data with landowner information and make it available to other state and local agencies and offices in user-friendly formats. Initial concerns were about security—what would happen to the data once they were outside of the department charged with managing them? Functional problems with data scale, competing priorities, and a shortage of state funding soon put the concept on a slower course.

TWRA was willing to house the GAP data on their system, because they understood the imperative for conservation planning and the need for better tools. The Departments of Environment and Conservation and Finance and Administration were willing to cooperate on a pilot project for employing the information on a limited basis. TLC and TWRA identified four counties for a pilot project—Lauderdale, Fayette, Polk, and Franklin. These counties were selected based on a blend of social and demographic variables, biological diversity, and associated threats. TWRA provided the data and help using it. TCL developed the relationships by working with local leaders, including elected officials, educators, citizen interest groups, and natural resource professionals.

The goal was to get conservation data integrated into local land-use decisions, and the results were mixed. Success can sometimes be defined by learning what not to do, and we learned to be sure to include the local Chamber of Commerce among the stakeholders being consulted. Getting the local university involved proved most helpful. Developing internal champions—the local planner and area natural resource professionals—was key. Even though the data's spatial resolution is too coarse for planning applications to small parcels, and the cost of upgrading landowner information ultimately limited results at the local level, the awareness and support generated by these initial efforts were key in passing the state's first "Smart Growth Legislation."

Tennessee's First "Smart Growth Law"

Public Chapter 1101, passed in 1998, called for cities and counties to evaluate local natural resource considerations before agreeing on the designation of areas for urban and rural development. The timeline designated for plans to be filed with the state was short, and counties did not yet have access to user-friendly GIS informa-

tion, so the act initially did little more than get most cities and counties to agree. However, this was no small feat in a state plagued by a frenzy of annexation. Public Chapter 1101 did provide that if the cities and towns could not agree on a county plan, all parties had to submit to arbitration and if that failed, the decision would be made by a panel of judges. Fayette, one of the counties in the pilot project, is the first and so far only county to be up for judicial review, and it is a textbook case for arguing the need for conservation planning.

TCL was asked by the court to submit a report outlining conservation considerations that, as a result of our work, the court should consider. In addition to species richness revealed by the GAP analysis data, our work exposed groundwater considerations based on research conducted by the USGS and the University of Memphis Groundwater Institute, and soil considerations based on research done on the New Madrid Fault by the Southeastern Earthquake Research Institute and data from the USGS and NRCS. Fayette County contains pockets of high biological diversity along stream banks and in some upland areas because it remains largely agricultural. The county is located over the recharge area for the Memphis aquifer, so the density and pattern of development could immediately affect local water supplies. The potential for soil erosion and liquefaction from an earthquake further argues limited development around rivers and streams. Testimony on the case ended just before Christmas; however, the judges and their planner are not expected to render a decision until mid-year because of the complexity of the case.

Public Land for the Public Good

In 1997, TCL was able to work with the University of the South, our partner on the Franklin County pilot project, and successfully advocate for the state to shift the location of a golf course being built at Tims Ford State Park, based on GAP data and habitat needs.

GAP data were once again employed in 2001 in a precedent-setting effort to limit development and promote conservation strategies on public land already set aside for development. The State of Tennessee found themselves trustee of 9,100 acres of public land when the Tims Ford Reservoir/Elk River Development Agency (TERDA) was "sunset" in 1991. The TERDA was established several decades earlier when economic development was a high priority for this rural area, which is now one of the fastest-growing counties in Tennessee. Proceeds of the land being sold were to be funneled to the school system.

The Department of Environment and Conservation found themselves in a unique position and asked the Tennessee Valley Authority to partner with them on developing an Environmental Impact Statement prior to disposing of the land. To their credit, both organizations proposed four options and gave preference to one calling for developing only 6,900 acres. TCL successfully invoked habitat and viewshed needs to eliminate development of an additional 800 acres and used habitat, open space, and water quality considerations to argue for the incorporation of conservation overlays on the land being developed. Adopting the latter was a precedent for TVA and the State of Tennessee. The first parcels will go up for bid in the spring of 2002. The bid specs will include design standards, and successful bids will be determined based on the quality of design in addition to dollars bid.

Funding a New GIS System for State Government

In 1999, the Tennessee General Assembly voted to fund the initial production phase of a statewide high-accuracy GIS project for state, local, and municipal governments. The pilot projects were successful, and now the state is working on an ambitious five-year plan to get all 95 counties included in the system. The GIS project is headquartered in the Office of Finance and Administration, but the needs of all departments are incorporated. Data from the new system, including GAP data, are being made available to county governments at an affordable rate (25 cents on the dollar). So far 23 counties have signed up for the new system. The association we began with this initially reluctant department in 1996 is now paying dividends in statewide spatial data. All of the TCL pilot counties will have their data sets by spring 2002.

Like so many states, Tennessee struggles with funding problems. Keeping this project funded is a concern and cannot be accomplished in the same time frame without matching federal funds. Keeping the project going requires vigilance and stakeholder support. However, forward-thinking people in state government are already looking at the day when all 95 counties are signed on and identifying systems large enough to manage calculations for the entire state rather than one region at a time.

Planting Seeds

Make no mistake, we recognize that the seeds planted six years ago by TCL and TWRA are not solely responsible for all of the legislation and policy decisions listed here. Witnessing a 16.9% population growth and almost 30% land use change helped crystallize the need in many people's minds. However, it is satisfying—especially on days when we are frustrated by the pace of an initiative—to look back and be reminded that we are planting seeds. Seeds grow into awareness and develop champions who seek the right opportunity to introduce an idea that soon takes root and begins to flower.

FINAL REPORT SUMMARIES

Idaho Gap Analysis Project

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The mission of the Gap Analysis Program is to prevent conservation crises by providing conservation assessments of biotic elements (plant communities and native animal species) and to facilitate the application of this information to land management activities (Gap Analysis Program 2000). This is accomplished through the following five objectives:

1. Map actual land cover as closely as possible to the alliance level (UNESCO 1973, Federal Geographic Data Committee 1997).
2. Map the predicted distribution of those terrestrial vertebrates and selected other taxa that spend any important part of their life history in the project area and for which adequate distributional habitats, associations, and mapped habitat variables are available.
3. Document the representation of natural vegetation communities and animal species in areas managed for the long-term maintenance of biodiversity.
4. Make all GAP project information available to the public and those charged with land use, research, policy, planning, and management.
5. Build institutional cooperation in the application of this information to state and regional management activities.

To meet these objectives, it is necessary that GAP be operated at state or regional levels but maintain consistency with national standards. Within the state, participation by a wide variety of cooperators is necessary and desirable to ensure understanding and acceptance of the data and forge relationships that will lead to cooperative conservation planning.

In 1989, with the support of the National Fish and Wildlife Foundation, Idaho conducted the initial research and development of the Gap Analysis Project concept and developed the prototype for national GAP projects. During the past decade, the National GAP office has updated standards for GAP products. New remote sensing and GIS technology have improved our ability to map and analyze Idaho's natural resources, while state and federal land use objectives have brought new challenges to the state. These changes have prompted Idaho to revisit its original GAP project and update its findings using new land cover information, revised species-habitat data, and an up-to-date map of land stewardship practices.

This second edition of Idaho GAP varies from the first in a few significant ways. First, our land cover mapping and subsequent classification have been conducted at a finer spatial resolution. The spectral footprint of the MSS imagery used in GAP I (1989) was 4 hectares; no habitat features smaller than 4 hectares could be detected, causing a broad-brush approach to both vegetation identification and habitat modeling for vertebrates (200-ha minimum mapping unit [MMU]). The Landsat TM imagery for GAP II (1996) produced vegetation information for each 0.09-ha area (30-m pixels), allowing evaluation of vegetation at a finer scale and the identification of minor land cover species of importance to the state (2-ha MMU). The finer scale from Landsat imagery is still considered broad-brush by biologists who study species in their discrete habitats, but the Landsat resolution meets GAP's objective to visualize the state's overall biodiversity. In addition to the finer scale, GAP II's vegetation classification came with values for slope, aspect, and elevation for each 30-meter pixel. This would prove useful in refining some of the WHR models for habitat specificity. Both vegetation classification systems identified groupings of forest, shrubland, grassland, and riparian, but the finer scale of the Landsat images also allowed us to quantify unique habitats for specialized species, such as reptiles and amphibians.

Wildlife Habitat Relationship Models were built on vertebrate life history information from peer-reviewed literature. GAP II built upon the foundational references on habitat affinity in Idaho used in GAP I, and reviewed major species-specific journal articles published between 1950 and 1998 to garner additional habitat information. Unfortunately, up until the past few years, most field researchers have failed to record useful habitat information in their published reports (Karl et al. 1999). Without knowledge of a species' use of slope or scale or elevation much of the additional information available in the Landsat land cover layer went unused.

Between the GAP I and GAP II stewardship products, a greater attempt was made, in concert with Conservation Data Center, to provide detailed information on each of the ownership types and management objectives. This is an ongoing project that will improve over the coming years. As it is, ID-GAP can now refine its identification of potentially threatened environments.

Land Cover Mapping

For ID-GAP, Idaho land cover was mapped in two sections. Redmond et al. (1996) at the University of Montana's Wildlife Spatial Analysis Lab (WSAL) mapped the northern part of the state as part of a U.S. Forest Service Region 1 land cover mapping effort. Homer (1998), at the Utah State University Remote Sensing/GIS Laboratory, mapped the southern part of the state as part of the Wyoming mapping initiative. Contracting with two different remote sensing labs, which were already mapping vegetation in adjacent states, expedited the development of Idaho's vegetation layer for gap analysis. It also created a minimally disjunctive land base on which to conduct subsequent research. Although the mapping endeavors were conducted independently, Homer's (1998) vegetation classification system was designed to compliment the earlier work of Redmond et al. (1996). Satellite imagery was acquired primarily from the growing seasons during 1992 and 1993, but some scenes were selected from other years (ranging from 1991 to 1995) to minimize cloud cover.

The Northern Idaho vegetation map was created from Landsat TM scenes and stored in a series of seven ARC/INFO grids (one per TM scene covering Northern Idaho). The database was built through a two-stage classification involving both unsupervised and supervised procedures. First, for each TM scene, an unsupervised classification of pixels was conducted. This pixel classification, based on Euclidean distance calculations, was designed to maintain patterns observed in a color composite of bands 4, 5, and 3. The resulting spectral classes were then regrouped and merged to 2-ha MMU (> 22 pixels). Next, a raster database was constructed in ARC/INFO where base regions (or raster polygons) were delineated, and attributes for each region were collected. Meanwhile, 7.5 minute quadrangles were selected and field sampled in 1994-95 by the U.S. Forest Service, Northern Region. These ground-truth plots were combined with plots from existing sources and passed to the WSAL, where they underwent a series of logical and positional tests to verify their accuracy and utility for supervised classification purposes. In all, 17,854 plots were compiled in the ground-truth database. Of these plots, 80% were used in the subsequent supervised classification, and 20% were used to conduct the accuracy analysis for the classification system. The supervised classification system assigned cover type labels using a "Nearest Member of Group" classifier. Decision rules were applied where necessary in assigning labels to vegetation, size class, and canopy cover. The riparian vegetation was mapped through a separate process. Using digital elevation data, predicted riparian zones were delineated, then spectral classes were selected to represent riparian vegetation within the zones at a 30 m pixel resolution.

For southern Idaho, mapping zones were used in an effort to optimize these criteria and gain desired resolution within acceptable budgetary and time lines. A mapping zone was defined as an independent mapping project area. (Vegetation training sites and classification were applicable only to this area.) With mapping zones, an effort was made to contain spatially similar ecological areas within a reasonable sample of TM pixels. It was determined that nine mapping zones would optimize this mapping effort. In each zone a master scene was selected, and surrounding scenes slaved into the master scene. A two-step approach of atmospheric standardization and histogram adjustment was used to mosaic the TM imagery. Cover-type class definition was based first on correlation with previous Utah and Nevada classifications, and second, with the classification scheme generated by the University of Montana. Signatures in each mapping zone were classified using the ERDAS (TM) ISODATA algorithm (Tou and Gonzalez 1974) to generate unsupervised spectral clusters. An iterative review of the clustering process was used to identify the optimum number of spectral clusters needed to characterize land-cover variation in each mapping zone. Cover-type modeling followed the protocol developed by Homer et al. (1997) and consisted of two phases: (1) statistical association of spectral classes with cover-types, and (2) ecological modeling based on ancillary information.

The resulting combined land cover data set consisted of 82 classes and was the highest-resolution, continuous land cover map yet to be produced for Idaho. Idaho's most extensive vegetation community was Basin Big Sagebrush (*Artemisia tridentata*) and Wyoming Big Sagebrush (*Artemisia tridentata wyomingensis*) across southern Idaho. It covered 34,787 square kilometers or 16.08% of Idaho's land. All sagebrush and shrub-steppe types combined constituted 33% of the Idaho landscape. Agriculture ranked second in land area with 29,029 square kilometers or 13% of land cover. Grassland and meadow vegetation communities occupied 11% of the Idaho landscape, with Perennial Grasslands comprising 46% of that area. Douglas-fir was the most common forest type (7%) in Idaho, and no other single forest species or forest community occupied more than 5% of the state landscape. The total forest area was 37% of the Idaho landscape. Riparian, wetlands, and marshes covered 2% of Idaho's landscape and were categorized in seven classification codes. Shrub-dominated riparian occupied the largest area with 0.87% of the total mapped riparian/wetland distribution. The combined sand and rock classifications occupied 2% of the landscape with the greatest portion of that distribution seen in exposed rock.

Assessed accuracy measures of the land cover map varied greatly between areas. Particular attention should be paid to the sample size for each cover type when interpreting the results. For the five scenes combined to create the north Idaho land cover map, producer's accuracy for those comparisons acceptable or better (3 or greater in the fuzzy matrix) ranged from 53.35% to 71.23%. Total percent correct measures for southern Idaho mapping units ranged from 65.5% to 79.3%. Overall percent correct for the southern Idaho land cover classification was 69.3%. Overall, total percent absolutely correct for the Idaho Land Cover Classification was 50.15%. Estimated kappa value for the Idaho Land Cover Classification was 0.4942.

Predicted Animal Distributions and Species Richness

Modeling of vertebrate distributions for ID-GAP followed a 7-step process. First, we compiled a list of species known to breed in

Idaho. Second, we collected occurrence and habitat association data for each species. Third, we used the occurrence data to approximate the range boundaries of each species in Idaho. Next, we assembled the habitat association information on breeding habitats into a format acceptable by our modeling programs. Fifth, we combined the range approximation with the coded habitat associations to produce a GIS model of the predicted distribution of each species. Sixth, biologists familiar with the distribution of Idaho's wildlife reviewed the models. Finally, each model was subject to an accuracy assessment with independent occurrence data.

Of species recorded in 10 or more of the accuracy assessment areas, 93.69% of the models were assessed to have greater than 80% correct present. For those species listed in 10 or more areas, the percent correct present ranged from 81.82 to 94.44% for amphibians, 55.56 to 100% for birds, 58.82 to 100% for mammals, and 76.47 to 100% for reptiles. Appendices E through H contain comments on the accuracy of each WHR model for birds, mammals, amphibians, and reptiles, respectively.

Species richness can provide a rough assessment of the diversity of wildlife within a given area. While species richness as an index of conservation effectiveness is very limited (e.g., does not account for representation or rarity, and tends to emphasize habitat and range edges), it is generally useful for characterizing regional biological diversity. We defined species richness as the number of species predicted to occur within a given unit. For ID-GAP, we investigated species richness by land cover type and by Environmental Monitoring and Assessment Program (EMAP) hexagon. Individual species' WHR model grids were combined and the number of species summed over each unit area. For calculations of richness by EMAP hexagon, we considered only native species that were determined to not be able to sustain their populations exclusively within human-developed landscapes.

Out of 379 species, the maximum predicted to occur in a single cover type was 235 (62.0%). Thus, no single cover type contained all species. Riparian cover types were predicted to be habitat for the most species in Idaho (Table 3.7). All of the riparian types (excluding wetland types) were predicted to have over 200 species using them as habitat. Following riparian areas, the next richest habitats were forested cover types. The most species-poor cover types (3 to 73 species) were alpine (perennial ice and snow, alpine meadow), urban, and non-vegetated cover types.

A total of 317 native, non-anthropogenic vertebrates were considered for analyses of hexagon richness in Idaho (Map 3.4). Of those, 254 were the most predicted to occur within a single hexagon (79.9%) and 80 were the least. Average number of species predicted to occur per hexagon was 184.6 with a standard deviation of 39.8 species. Areas of highest species richness (more than 233 species) occurred in southern Idaho along the Snake River Plain. These areas have many lakes, reservoirs, and wetlands and thus provide a wide variety of habitats for many species. Lowest species richness was observed in the subalpine-forested uplands and alpine areas of northern and central Idaho, the shrub-steppe habitats of Owyhee County, and the largely nonvegetated lava fields of southern Idaho. While species richness is lower in these regions, they provide unique habitats to some species that are found nowhere else in the state (e.g., northern bog lemming [*Synaptomys borealis*] in northern Idaho, rock squirrel [*Spermophilus variegates*] in Owyhee County). This highlights one of the shortcomings of assessing conservation status using species richness.

Land Stewardship Mapping

To fulfill the analytical mission of GAP, it is necessary to compare the mapped distribution of elements of biodiversity with their representation in different categories of land ownership and management. We use the term "stewardship" in place of "ownership" in recognition that legal ownership does not necessarily equate to the entity charged with management of the resource, and that the mix of ownership and managing entities is a complex and rapidly changing condition not suitably mapped by GAP. At the same time, it is necessary to distinguish between stewardship and management status in that a single category of land stewardship such as a national forest may contain several degrees of management for biodiversity. The purpose of comparing biotic distribution with stewardship is to provide a method by which land stewards can assess their relative amount of responsibility for the management of a species or plant community, and identify other stewards sharing that responsibility. This information can reveal opportunities for cooperative management of that resource, which directly supports the primary mission of GAP to provide objective, scientific information to decision makers and managers to make informed decisions regarding biodiversity.

After comparison of biotic occurrences to stewardship, it is also necessary to compare with categories of management status. The purpose of this comparison is to identify the need for change in management status for the distribution of individual elements or areas containing high degrees of diversity. Such changes can be accomplished in many ways that do not affect the stewardship status. GAP currently uses a scale of 1 to 4 to denote relative degree of maintenance of biodiversity for each tract. A status of "1" denotes the highest, most permanent level of maintenance, and "4" represents the lowest level of biodiversity management, or unknown status. In reality, there exists a gradient of human impacts on the land with no landscape unmodified to some extent by human activities, but this categorization is useful for analytical purposes.

Stewardship map data were assembled from two sources. Data at 1:100,000 scale were carried forward from previous work at the Idaho Gap Analysis Lab completed from 1989-1991 (Caicco et al. 1995). That data set included major administrative land units including those under federal, state, tribal, and private ownership.

Status 1 and 2 polygons, digitized at 1:24,000 scale, were provided by the Idaho Conservation Data Center (CDC) and were combined with existing 1:100,000 data. Sliver polygons, resulting from the discrepancy between parcel boundaries digitized at disparate scales, were removed, as were those polygons smaller than 2 hectares, the minimum mapping unit (MMU) for Idaho Gap Analysis. Polygons

in the land stewardship coverage were assigned protection status values from 1 to 4 based on their owner and management status tracked by the Idaho Conservation Data Center.

Public lands (federal and state) comprised approximately 14,980,800 ha (69.31%) of Idaho. State lands accounted for approximately 1,109,400 ha (5.13%) of Idaho. Private lands made up 6,448,100 ha (29.83%) of Idaho. Of this amount, 11,200 ha (0.174%) is in status 1 management. The Nature Conservancy owns and manages 94.53% of all private status 1 lands in the state (Table 4.2).

The area of Idaho land in status 1 and 2 was 321,500 ha (1.49%) and 2,229,500 ha (10.32%), respectively. Protection status 3 lands covered 12,442,600 ha (57.57%) of Idaho, and 6,437,000 ha (29.78%) were in status 4. The majority of status 2 lands were contained in Idaho's wilderness area complex, managed by the USFS (1,556,900 ha, 69.83% of status 2 lands). Other major status 2 land managers were the Department of Energy (Idaho National Engineering and Environmental Laboratory [INEEL] 231,600 ha, 10.39%), wildlife protection areas and wildlife refuges managed by the U.S. Fish and Wildlife Service (33,000 ha, 1.48% of status 2 lands) and Idaho Department of Fish and Game (Wildlife Management Areas, 119,500 ha, 5.36%).

Analysis Based on Stewardship and Management

The primary objective of GAP is to provide information on the distribution and status of several elements of biological diversity. Intersecting the land stewardship and management map with the distribution of the elements resulted in tables summarizing the area and percentage of total mapped distribution of each element in different land stewardship and management categories. The data were formatted to allow users to query the representation of each element in different land stewardship and management categories, as appropriate to their own management objectives. This formed the basis of GAP's mission to provide landowners and managers with the information necessary to conduct informed policy development, planning, and management for biodiversity maintenance.

Although GAP seeks to identify habitat types and species not adequately represented in the current network of biodiversity management areas, it is unrealistic to create a standard definition of "adequate representation" for either land cover types or individual species (Noss et al. 1995). A practical solution to this problem is to report both percentages and absolute area of each vegetation type or vertebrate species in biodiversity management areas, as described above, and allow the user to determine which types are adequately represented in natural areas based on detailed studies of the ecology, population viability assessments, as well as studies of the spatial and temporal dimensions of ecological processes. Clearly, opinions will differ among users, but this disagreement is an issue of policy, not scientific analysis. We have, however, provided a breakdown along five levels of representation (0-<1%, 1-<10%, 10-<20%, 20-<50%, and >=50%). The <1% level indicates those elements with essentially none of their predicted distribution in protected areas. Levels 10%, 20% and 50% have been recommended in the literature as necessary amounts of conservation (Odum and Odum 1972, Specht et al. 1974, Ride 1975, Miller 1984, Noss 1991, Noss and Cooperrider 1994), although biologically defensible goals may be much higher (Soulé and Sanjayan 1998).

Of Idaho's 71 mapped natural vegetation cover types (excluding 1000s, 2000, 3102, 5000, 9800, 9900), five had less than 1% of their total area represented in the combined protected statuses of 1 and 2. Twenty-six cover types had between 1% and 10% of their total area in status 1 and 2 lands. Nine cover types identified by the ID-GAP project had more than 50% of their total area in status 1 and 2 lands.

For the analysis of vertebrate distributions against land stewardship, we evaluated only those species that were not introduced or considered strongly associated with human-developed habitats (317 of 379 total vertebrate species modeled). We found 123 vertebrate species (38.8% of all 317 vertebrate species considered) with less than 10% of their predicted habitat on status 1 and 2 lands. This included 61 bird species (31.6% of all bird species considered), 38 mammals (42.2% of all mammal species considered), 16 reptiles (76.2% of all reptiles species considered), and 8 amphibians (61.5% of all amphibian species considered). The Clark's grebe (*Aechmophorus clarkii*) was the only species to have greater than 50% of its predicted habitat in status 1 and 2 lands.

Conclusions and Implications

At least 43.7% of natural land cover types and 38.8% of native, non-anthropogenic terrestrial vertebrates have been identified by ID-GAP as having levels of occurrence on lands managed for the long-term maintenance of biological diversity below what may be required for maintenance of viable populations. These underprotected (or underrepresented) land cover types and vertebrate species occur mostly at lower elevations under a variety of land stewardships including substantial areas of private ownership.

This project has provided Idaho with the most spatially refined and thematically detailed statewide compilation of information on Idaho's land cover types, vertebrate distributions, and land conservation status. These data should be considered an update to any previous information created as part of the ID-GAP program, and while more accurate and detailed data may exist for localized parts of Idaho, the data presented here is an enhancement over other conservation data sets currently being used statewide. Using these data, a myriad of research opportunities now exist.

To increase the utility of these data layers and their useful life span, continuing research needs to be directed toward three main areas: (1) further assessing the quality, appropriate uses, and limitations of the existing data layers; (2) refining the existing data based on continuing research, new data, and identified errors; and (3) developing methods to apply the data to real-world problems and applications affecting land use planning, management and conservation. There is much work yet to be done to refine the ID-GAP products and develop them into an indispensable tool for conservation planning in Idaho. Along these lines, we make the following suggestions for initial steps to improve the quality and usability of ID-GAP data:

1. further accuracy assessment of existing data layers,
2. periodic updates to the Idaho land cover map,
3. continual updating of the vertebrate habitat models,
4. continual updating of the Idaho land stewardship layer,
5. development of a system to disseminate ID-GAP data and support users.

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West Virginia Gap Analysis Project

JACQUELYN M. STRAGER AND CHARLES B. YUILL
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The West Virginia Gap Analysis Project (WV-GAP) was conducted for the state of West Virginia in accordance with national Gap Analysis Program standards. WV-GAP involved participation from universities, state and federal agencies, and non-profit conservation organizations, taking advantage of the expert knowledge and background of many individuals. Specific objectives of WV-GAP included mapping land cover, mapping predicted distributions for vertebrate wildlife species, conducting analysis of representation of wildlife species and cover types with respect to land stewardship, and providing these results to managers and other interested parties.

WV-GAP was conducted for the entire state of West Virginia, encompassing over 60,000 km^2 and portions of the Allegheny Plateau, Allegheny Mountains, and Ridge and Valley physiographic regions.

Land Cover Classification and Mapping

For WV-GAP, West Virginia's land cover was mapped to the ecological complex (multiple Alliance) scale. Twenty-six different land cover categories were mapped, including eight different forested land cover types. Land cover was mapped from classification of Landsat TM imagery acquired between 1992-1994. Land cover classification was augmented through the use of aerial videography flights from 1994-1996, as well as ground sampling plots throughout the state and various ancillary data sets.

Forested cover types clearly dominate the West Virginia landscape. The most common cover type in West Virginia was found to be diverse mixed mesophytic forests (38% of WV's area). Land cover has the potential for future rapid localized change in West Virginia due to mining, timbering, and other land use activities.

Predicted Vertebrate and Butterfly Species Distributions

Predicted distributions of 434 species of butterflies, amphibians, birds, reptiles, and mammals were mapped using the WV-GAP land cover data set, wildlife habitat relationship models, and general range maps. Accuracy assessment of wildlife distribution maps was conducted by comparing predicted species with known species checklists for various locations around the state.

Species richness varies across the state, with higher species richness in general across the Allegheny Mountains. Species distributions were modeled according to standard GAP methodology, with the exception of wetland and riparian amphibians and reptiles. These species were modeled using a special wetland/riparian habitat model developed by WV-GAP, instead of the WV-GAP land cover model.

Limitations of the various model elements in the animal distribution mapping reflect a general lack of comprehensive statewide information for many species. While the gap analysis mapping techniques used here are not an alternative to more detailed ecological inventory, the "snapshot view" of species provided by WV-GAP is a useful contribution to future work and planning in the state.

Land Stewardship and Management

WV-GAP compiled a map of current land stewardship within the state, as of 1999. Each parcel was associated with land steward (managing agency or entity) and available information on management objectives. WV-GAP then assigned GAP management status rankings to parcels to provide a measure of the consideration given to biodiversity conservation for each parcel. Status 1 denotes the highest level of biodiversity maintenance, with status 4 representing the lowest level. Approximately 10% of the state of West Virginia falls under management of either federal or state agencies, with varying levels of biodiversity conservation-related management objectives. The largest single publicly owned entity in the state is the Monongahela National Forest. The majority of the status 1 lands in West Virginia occur in the higher elevations of the Allegheny Mountains, while the majority of the public lands in West Virginia are classified as status 3, including National Forest lands and other multiple-use areas.

Analysis Based on Stewardship and Management

Gap Analysis seeks to "identify habitat types and species not adequately represented in the current network of biodiversity management areas" (GAP Handbook, Preface, Version 1, Page I.) WV-GAP evaluated the potential conservation status of wildlife species and natural land cover types by tabulating the total land area of each species' or cover type's predicted distribution within various land management status categories (see above).

From this analysis, conservation "gaps" or needs for West Virginia have emerged. Results indicate that species utilizing edge or open habitats are less likely to be protected in West Virginia than are interior forest species. Special analyses of butterflies, wetland/riparian species, and cave-dwelling wildlife also offer perspectives that are unique to the WV-GAP project in relation to other states' GAP work.

Conclusions and Management Implications

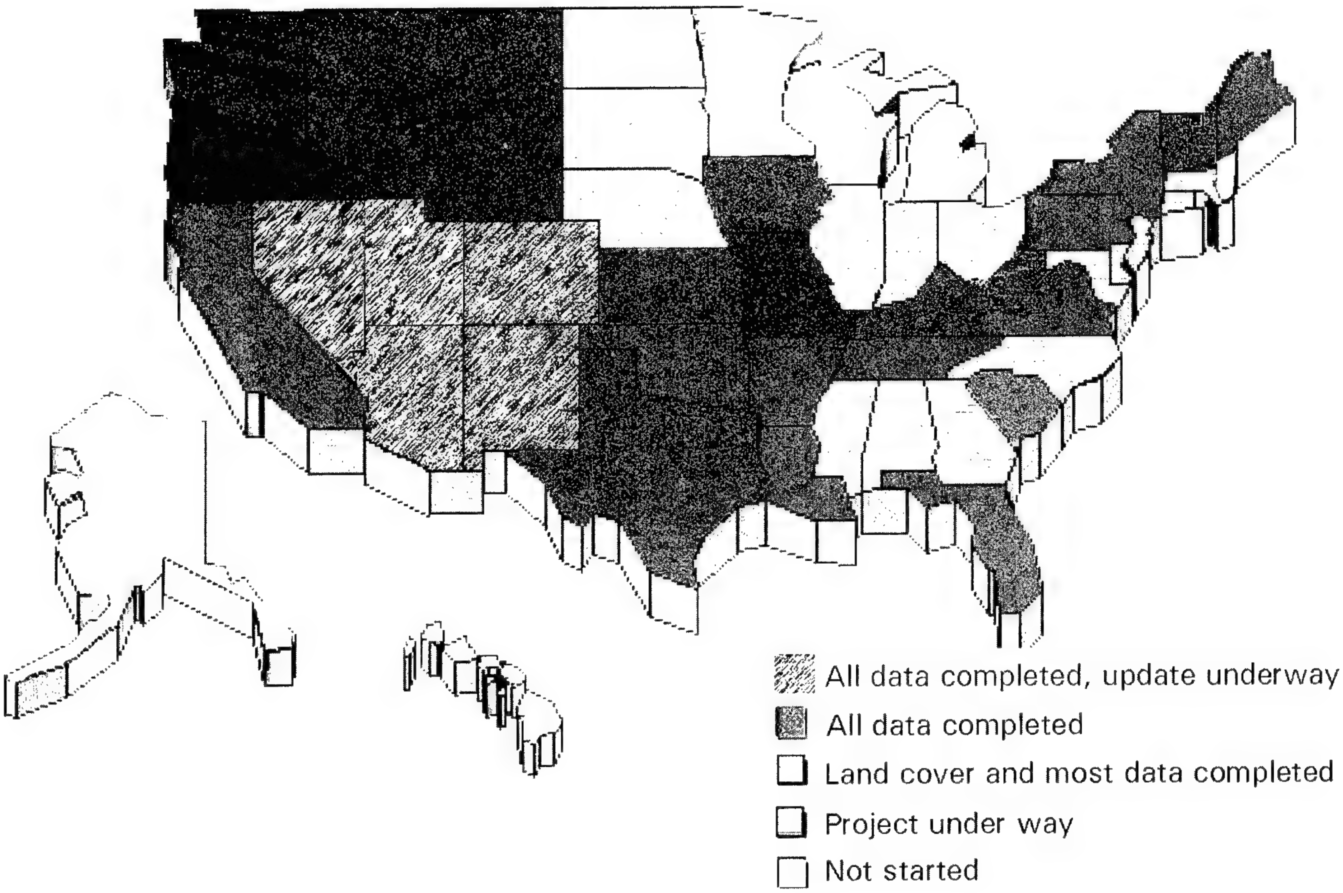
Gap Analysis methods are used to identify land cover types and terrestrial animal species that would benefit from additional conservation attention before they become rare or imperiled. While useful as a broad-scale, snapshot picture of biodiversity distribution and conservation needs for the state, WV-GAP is not a substitute for long-term monitoring or extensive biological inventory work. Limitations of the WV-GAP results serve to highlight communities or species in need of more extensive statewide evaluation.

Data Use and Availability

The main geospatial products of the WV-GAP effort are land cover, land stewardship, and predicted wildlife distribution models for the entire state. Associated WV-GAP database products include wildlife/habitat relationship data, wildlife range data, and literature references. Geospatial and database products will be made available through the National Gap Analysis Program on CD-ROM or via Internet download. Selected data products are also available from the West Virginia GIS Technical Center at West Virginia University. The WV-GAP home page (http://www.nrac.wvu.edu/gap/) provides general information for WV-GAP as well as links to the National Gap Analysis Program.

STATE PROJECT REPORTS

(Status as of December 2001)



All completed products and reports will be available through the GAP Web site at http://www.gap.uidaho.edu/Projects/. Drafts and other products may be obtained from the state project PI as noted.

Alabama

Under way

Anticipated completion date: December 2005

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silvaal@auburn.edu, (334) 844-9295

Land cover: We have statewide leaf-off coverage of ETM+ imagery and are awaiting the acquisition of leaf-on scenes from the current MRLC contract. We have completed unsupervised classifications of the leaf-off imagery. During fall 2001, we acquired digital aerial videography of approximately 3,500 miles of flight line, completing this phase of our project. Digital video will be interpreted and used to select training regions for further classification. The year 2002 will be spent primarily on building our library of training regions.

Animal modeling: We have developed a peer-reviewed list of vertebrates to model and will be initiating modeling and database-related activities during the coming year.

Land stewardship mapping: Land stewardship mapping is approximately 85% complete. We expect to complete this theme during the coming year and to build an associated database.

Alaska
Not started

Arizona
Update under way (see Southwest Regional GAP)

CDs from first-generation GAP will be published this summer.

Arkansas
Complete (see http://www.cast.uark.edu/gap/)

California
Complete (see http://www.biogeog.ucsb.edu/projects/gap/gap_home.html)

Colorado
Update under way (see Southwest Regional GAP)

CDs from first-generation GAP will be published this summer.

Connecticut
(see Massachusetts, Connecticut, & Rhode Island)

Delaware
(see Maryland, Delaware, and New Jersey)

Florida
Complete (see http://www.wec.ufl.edu/coop/gap/)

Georgia
Under way

Anticipated completion date: October 2002

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Matthew J. Elliott, Project Coordinator
Natural Resource Spatial Analysis Laboratory
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Land cover: A statewide general land cover map has been completed and accuracy assessed. Accuracy assessment of the general land cover map was accomplished through digital video; overall accuracy was 85%. From the general land cover, we have begun mapping vegetation alliances. A set of decision rules has been developed to make the transition from general land cover categories to alliances. We anticipate completion of alliance mapping by April 2002.

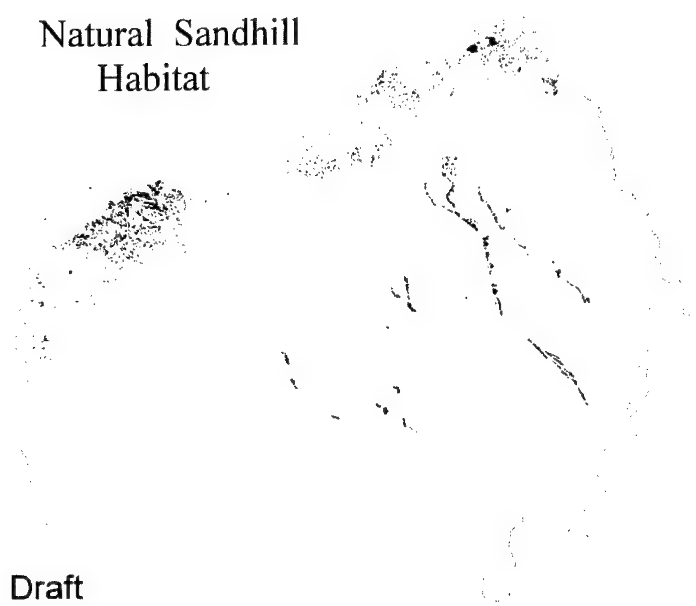

Figure 1. Natural sandhills habitats on the Georgia Coastal Plain.

Animal modeling: Habitat association databases have been completed for all taxa. All of the associations are currently out for review. An interactive form developed in Microsoft Access allows reviewers to make changes and add comments in the database. We have completed point occurrence databases for both herps and mammals. Georgia's Department of Natural Resources Nongame Wildlife Division provided valuable assistance in compiling herp records, while the Game Management Division helped with a number of mammal distributions. The Nongame Division's Breeding Bird Atlas was our primary source for bird occurrence data. General range maps for all taxa are currently out for review. We are ready to begin writing final models for species distributions, pending modifications from reviewers.

Land stewardship mapping: The stewardship layer was completed in 1999. Subsequent land purchases by the State of Georgia have

been incorporated into an updated version. We will include other acquisitions that occur before completion of the project.

Other accomplishments and innovations: The initial general land cover map will provide the base layer for the Georgia Land Use Trends (GLUT) project, which analyzes land cover change between 1974–1998. We have completed a land cover map for Georgia from 1974 and begun analyses of changes. Additional land cover maps from 5-year increments should be completed over the next year.

We have developed innovative methods for predicting distributions of stream salamanders and other aquatic herps using hydrologic models. We expect to expand and improve upon them before project completion.

Aquatic GAP: Georgia has initiated an Aquatic Gap Analysis Project in partnership with Alabama. We will be working in the Alabama-Coosa-Tallapoosa and Apalachicola-Chattahoochee-Flint river basins.

Hawaii

Under way

Anticipated completion date: June 2005

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Land cover: The Hawaiian entry to the NVC has been expanded to include16 plant associations identified as invasive-dominated. The description of these nonnative species assemblages will enable HI-GAP to accurately define variation within nonnative-dominated land cover along with the mapping of native-dominated plant associations. This work was done in conjunction with the development of a crosswalk classification system, which ties the NVC to the more detailed avian fauna habitat mapping effort being produced through the Hawaii Forest Bird Interagency Database Project (HFBIDP) at the Pacific Islands Ecosystem Research Center.

A statewide cloud-free LandSat TM imagery set is nearly in place. Images are still being sought for notorious cloud-cover areas, and multiple-date TM imagery is being sought for areas where only a single cloud-free coverage is in place. An IKONOS consortium is being formed by the Hawaii Natural Heritage Program (HINHP), which will enable land managers in Hawaii to join together and share image purchases. HI-GAP is administrated through HINHP and will soon have access to a large library of recently collected high-resolution spectral imagery. While statewide coverage may be a long-term goal, this imagery should assist in the development of the statewide LandSat TM land cover.

HFBIDP is currently mapping upland forested areas in Hawaii in areas where native Hawaiian forest birds are known to occur. Imagery and classification techniques are being transferred between the HFBIDP effort and the HI-GAP land cover mapping team.

Animal modeling: More than 3,000 database records from the Hawaii Stream Assessment conducted by the State of Hawaii's Division of Aquatic Resources have been geocoded to stream segments. A distributable GIS data set has been produced and reviewed. Refinements are ongoing. The data set is the most comprehensive distribution of native aquatic biota currently available for Hawaii.

In addition to the traditional indigenous vertebrate mapping, HI-GAP is forming a group to undertake mapping of invasive vertebrates. In Hawaii, invasive pig, goats, deer, sheep, cats, mongoose, and rats all pose significant threats to native biodiversity. Statewide and islandwide distribution data for these critical threats is not currently available. HI-GAP hopes to integrate existing data, fill gaps, produce spatial data sets, and disseminate data on the distribution of invasive vertebrates. This important but controversial effort is going through a thorough internal scoping phase, as a strong response is expected both from land management agencies and local communities.

Land stewardship mapping: Stewardship mapping is underway. Initial draft maps and data sets have been produced and distributed (Figure 1). Review is ongoing and an updated version is expected in the spring.

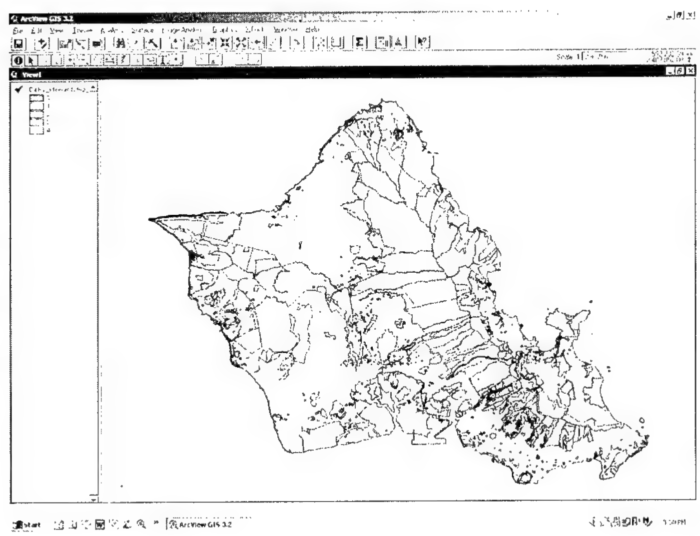

Figure 1. Stewardship layer for the island of Oahu. Parcel data from the City and County of Honolulu were used to derive this map layer.

Idaho

Update near completion

Anticipated completion date: May 2002

Contact: Leona K. Svancara
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Land cover: The Idaho land cover layer and final report chapter are complete. The land cover classification recognizes 81 cover types and is mapped at a resolution of 0.09 ha with a 2 ha MMU. The land cover data, metadata, and final report chapter can be downloaded at http://www.wildlife.uidaho.edu/idgap.htm or by contacting the Idaho Cooperative Fish and Wildlife Research Unit.

Animal modeling: Second-generation wildlife habitat relationship models have been completed for 379 terrestrial vertebrates in Idaho. The models are stored on Idaho's Web site as georeferenced TIFF images with a native resolution of 0.09 ha. Accuracy assessments of the models were completed in 2001 and the results included in the metadata. The models and metadata can be downloaded at the URL above or by contacting the Idaho Cooperative Fish and Wildlife Research Unit.

Land stewardship mapping: The revised Idaho land stewardship database is also complete. This data set represents a significant improvement over the original Idaho land stewardship layer by increasing spatial resolution to a 2 ha MMU and incorporating many of the smaller managed areas in Idaho. This data set, its metadata, and final report chapter are available for download at the URL above or by contacting the Idaho Cooperative Fish and Wildlife Research Unit.

Analysis: Analysis of the protection status of Idaho's land cover types and wildlife habitat distributions is complete. We also completed a gap analysis of geomorphologic and climatic features in Idaho.

Reporting and data distribution: The final report for ID-GAP is in draft format and should be completed by spring 2002. (See report summary on page 43.) Final updates are being made to the metadata.

Other accomplishments and innovations: We have developed programs to create hypergrids (grids containing the distributions of all input grids in condensed, binary form) in order to facilitate the identification of areas that satisfy multiple selection criteria including species richness, species protection status, size of area, and contiguity of area.

2001-2002 GAP-related publications include:

Wright, R.G., J.M. Scott, S. Mann, and M. Murray. 2001. Identifying unprotected and potentially at-risk plant communities in the western USA. *Biological Conservation* 98:97-106.

Scott, J.M., F.W. Davis, R.G. McGhie, R.G. Wright, C. Groves, and J. Estes. 2001. Nature reserves: Do they capture the full range of America's biological diversity? *Ecological Applications* 11:999-1007.

Karl, J.W., L.K. Svancara, P.J. Heglund, N.M. Wright, and J.M. Scott. 2002. Species commonness and the accuracy of habitat-relationship models. Pages 573-580 in J.M. Scott, P.J. Heglund et al., editors. Predicting species occurrences: Issues of accuracy and scale. Island Press, Washington, DC.

Illinois

Under way

Anticipated completion date: December 2002

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Land cover: As part of the Interagency Land Cover Classification Project between the Illinois State Geological Survey, Illinois Department of Natural Resources, and the Illinois Department of Agriculture's National Agriculture Statistics Services, an updated statewide Level I land cover classification was completed in September 2001, using 1999 and 2000 TM imagery. To speed up the classification process, we use these Level I classifications for the remaining scenes in the state and will classify them to Level II (community level) for GAP. Current completed classified scenes can be found in Figure 1. Editing and accuracy assessment are being started on TM scene 2233.

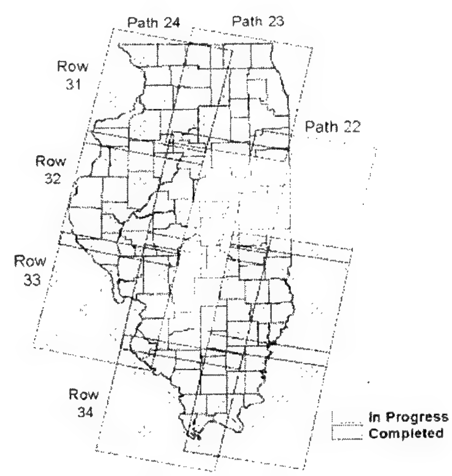

Figure 1. Status of landcover map for Illinois

Animal modeling: Draft vertebrate models have been completed and reviewed by scientists for all mammals, reptiles, and amphibians (Figure 2.) The bird databases are 90% complete. We will begin creating hexagon maps for all bird species in January 2002. We are continuing work on our habitat associations database for mammals, amphibians, birds, and reptiles.

Thirteen-lined Ground Squirrel
(Spermophilus tridecemlineatus)

Figure 2. Predicted vertebrate range map

Land stewardship mapping: We have developed a land stewardship map for Illinois, attributed general ownership categories, and assigned management status levels. The GAP coding scheme for land units has been assigned to each property. The database includes federal, state, and county properties. In Illinois counties control the stewardship of about 500 properties. This coverage is complete and is currently being reviewed and updated as needed.

Analysis: We have completed some preliminary analysis using amphibian, bird, mammal, and reptile locational data to create species richness maps using the EMAP hexagons. Preliminary species richness maps for birds were created using only locational data from Illinois Breeding Bird Atlas, Illinois Spring Bird count, the U.S. Department of Interior Bird Banding Lab, and the Illinois Natural Heritage Database. Final species richness maps for birds will be created again using all available databases (including those listed above and Illinois Natural History Survey collections, Breeding Bird Survey, Audubon's Christmas Bird Count, Project Feeder Watch, and the Great Backyard Bird Count). We have also conducted preliminary analysis of predicted distributions for species that occur in southern and northeastern Illinois. We will do more analysis as our species and vegetation mapping progresses.

Reporting and data distribution: We have started writing some portions of the final report and will continue as our project progresses.

Other accomplishments and innovations: The IL-GAP Web page can be reached at www.inhs.uiuc.edu/cwe/gap/gapintro.html.

Listed below are projects that are starting up, ongoing, or have been completed using the land cover database of Illinois as well as other data developed as part of IL-GAP.

- Applying spatial information technology to ecological risk assessment in Illinois. T. Weicherding, J. Levengood, S. Lavin.
- Distribution of Franklin's ground squirrel in Illinois. J. Martin, E. Heske, and J. Hofmann.
- Population ecology and habitat use of eastern wild turkeys in Illinois. P. Hubert, T. Van Deelen, P. Brown, and J. Garver.
- Fox and coyote ecology in central Illinois. T. Gosselink, T. Van Deelen, R. Warner, and P. Mankin.
- Deer in the urban ecosystem. D. Etter, T. Van Deelen, and R. Warner.
- Identification and classification of critical wildlife habitat. P. Brown, J. Aycrigg, and L. Suloway.
- Map Illinois. J. Aycrigg, D. Stigberg, J. Westervelt, and M. Joselyn.
- Effects of traditional habitat and ecosystem management on the population ecology of northern bobwhite. J. Seigrist and J. Brawn.
- Urban white-tailed deer as biomonitors for zoonoses in Chicago, Illinois. K. Hollis and R. Warner.

Indiana

Near completion

Anticipated completion date: August 2002

Contact: Forest Clark
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forest_clark@fws.gov, (812) 334-4261 x206

Land cover: Land cover is complete.

Animal modeling: Models are complete, now undergoing review and revision.

Land stewardship mapping: Land stewardship mapping is complete.

Analysis: Analysis will begin in early 2002.

Reporting and data distribution: Completed data are distributed through our regional server at the USGS Upper Midwest Environmental Sciences Center in LaCrosse, Wisconsin (contact Dan Fitzpatrick at (608) 781-6298 or Daniel_Fitzpatrick@usgs.gov).

Iowa

Near completion

Anticipated completion date: January 2002

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Bruce W. Menzel, Co-PI
Professor and Chair, Department of Animal Ecology
Iowa State University, Ames
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The Iowa Gap Analysis Project (IA-GAP) has finished its fourth and final year in 2001. The IA-GAP home page is accessible at http://www.iowagap.iastate.edu/.

Land cover: Land cover mapping is 100% complete. Final maps will be published in the final report and on the IA-GAP Web site. Data can also be viewed on the Iowa Geographic Image Map server at http://ortho.gis.iastate.edu/gaplandcover/gap_lc.html.

Animal modeling: Models have been completed for about 98% of all species. Iowa has been a cooperator in the Upper Midwest vertebrate modeling initiative along with North and South Dakota. Final distribution maps will be published in the final report and on the IA-GAP Web site.

Land stewardship mapping: Stewardship mapping and attribution is 100% complete. Final maps will be published in the final report and on the IA-GAP Web site. The IA-GAP stewardship image map server can be accessed at http://baykal.gis.iastate.edu/gapims/.

Analysis: Analysis is 100% complete. Final maps will be published in the final report and on the IA-GAP Web site.

Reporting and data distribution: Final maps will be published in the final report and on the IA-GAP Web site.

Aquatic GAP: The Iowa Rivers Information System (IRIS) project started with Iowa DNR as partner. Funding for a 3/4-time position was established through 6/02. More information can be found at http://mombasa.gis.iastate.edu/iris/iris.htm. A proposal was accepted for Iowa Aquatic GAP in August 2001. Staff was sent to an Aquatic GAP training session in Columbia, Missouri, in November 2001. PIs are involved in regional coordination with KS, MO, and NE.

Goals for 2002 are to (1) build the spatial database for Aquatic GAP and IRIS with the DNR's GIS Section using the National Hydrologic Dataset (NHD); (2) collect and add specific data attributes to the IRIS spatial structure; (3) regionalize data sets with KS, MO, and NE; and (4) integrate IRIS into a GIS environment where queries can be done for location or attribute information from a user's desktop. This will involve writing programming code in an ArcView environment using Avenue, Visual Basic, or C++.

Other accomplishments and innovations:

<u>Land cover accuracy assessment</u> – Final report submitted to EPA Region VII. The final report can be viewed on the IA-GAP home page (http://www.iowagap.iastate.edu/).

<u>NatureMapping</u> – In 1999, Iowa State University Extension Wildlife Programs began offering the Iowa NatureMapping Program to a wide-ranging audience. NatureMapping, a citizen-based wildlife monitoring program, is an education and outreach component of IA-GAP. Reliable, accurate, and up-to-date information about Iowa's wildlife collected by Iowans will give those considering decisions such as wildlife management and research, urban development, or conservation and preservation a valuable layer of data not otherwise available in traditional land use planning. NatureMapping is a way to collect large data sets while reconnecting people to their local resources. Final maps will be published in the final report and on the IA-GAP Web site.

<u>Iowa Geographic Information Image Server</u> – The server is serving orthophotos, topographic maps, and other Iowa grid data from http://ortho.gis.iastate.edu. This service is heavily used by IA-GAP and our cooperators as well as many other Iowa users for a variety of applications. The goal for 2002 is to update storage to provide data at higher resolution and serve more data, including integrating vector data and new Iowa color infrared photography coordinated by the Iowa DNR.

Kansas

Near completion

Anticipated completion date: April 2002

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Land cover: The land cover layer and accuracy assessment are finished. The land cover layer can be viewed or downloaded at http://mapster.kgs.ukans.edu/dasc/catalog/coredata.html.

Animal modeling: The wildlife habitat relationship models and draft models are completed for all 364 vertebrates. Experts have reviewed 80% of the vertebrate models, and 78% have been finalized. We anticipate having all models reviewed and finalized by February 2002. None of the vertebrate maps have been validated.

Land stewardship mapping: The stewardship boundary layer is 100% complete relative to land unit boundaries. Data from surveys have been entered into attribute tables used to assign status codes to all land units. Status codes have been assigned to units in the stewardship layer, and the majority of these codes have been reviewed by the appropriate state and federal agencies or nongovernmental organizations. Review of remaining status codes should be com-

pleted by mid-February 2002.

Analysis: We are currently working on methods for the gap analysis, which should be completed by the end of March 2002.

Reporting and data distribution: We expect to complete reporting and data distribution within the next four months.

Aquatic GAP: A meeting with local stakeholders was held in November 2001, at which representatives from various state, federal, and private agencies expressed a strong interest in an Aquatic GAP project for Kansas. In addition, we received input from agency personnel on the potential uses of Aquatic GAP. We have completed the initial processing of the National Hydrology Data set, which will be used as a base layer (i.e., by valley segments) to link biological and physical attribute data. We are also in the process of constructing a relational database with fish and mussel data provided by the Kansas Department of Wildlife and Parks and Kansas Department of Health and Environment.

Other accomplishments and innovations: We are currently conducting a pilot study to examine the feasibility of developing the KS-GAP vertebrate database as a discovery tool for elementary students in Kansas. We have also received continuing funds from the Kansas Department of Wildlife and Parks to develop the KS-GAP vertebrate database into a decision support system for resource managers in Kansas.

Kentucky

Near completion

Anticipated completion date: September 2002

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Land cover: The final version of the statewide vegetation map is complete. A first draft of the vegetation chapter has been written and is under review.

Animal modeling: Modeling of the predicted distributions of terrestrial vertebrate species has been completed. Land cover, digital elevation models, and National Wetland Inventory data were the basic input layers for our models. These layers were manipulated to refine our predicted species' distributions. Most of these refinements were a consequence of creating an edge buffer around map units or limiting a predicted distribution due to elevation constraints. All layers were created in or converted to ARC/INFO Grid (raster) format, with a cell size of 30 meters. All of our modeling was performed in the ARC/INFO Grid environment. We used one model (i.e., AML) consisting of many different subprograms for all species in order to maintain quality control over the modeling process.

Land stewardship mapping: The land stewardship layer (including metadata) is complete. A first draft of the stewardship chapter has been written and is under review.

Analysis: Land stewardship and vegetation analyses are complete. We are currently completing the gap analysis for the vertebrate species using the final stewardship layer. We anticipate that the analysis will be complete in spring 2002. The conclusions and management implications chapter of the final report is being written.

Reporting and data distribution: The goal for 2002 is to have the entire report completed, reviewed, and accepted by National GAP by September 2002.

Other accomplishments and innovations: We have worked with the Kentucky Department of Education and University of Kentucky Extension Service to produce middle school and high school teaching units using KY-GAP data. Received a $6,000 grant from BRD to conduct teacher workshops in June 2002 to develop teaching modules.

Louisiana

Complete (see http://sdms.nwrc.gov/gap/gap2.html)

CDs have been completed and distributed.

Maine

Complete (see http://wlm13.umenfa.maine.edu/progs/unit/gap)

Maryland, Delaware, and New Jersey

Near completion

Anticipated completion date: September 2002

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Land cover: Land cover mapping for the three-state area was completed during 2001. An accuracy assessment was conducted with nearly 2,500 points randomly selected from the project video. The final fuzzy accuracy assessment calculations will be completed early

in 2002.

Animal modeling: Models have been developed for all vertebrates, and distribution maps are currently being generated to be distributed for expert review beginning in January 2002.

Land stewardship mapping: The land stewardship mapping for the project was completed in 2001.

Analysis: The tables for the land cover analyses have been created. Early in 2002, the tables for the vertebrate layer will be completed. The gap analysis for the project will be completed by spring 2002.

Reporting and data distribution: The final report development is well under way with the methods sections completed for each chapter. Results for land cover and stewardship were completed in 2001. The complete report will be accomplished by July 2002.

Massachusetts, Connecticut, & Rhode Island

Near completion

Anticipated completion date: December 2002

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Land cover: Although the land cover map was completed in 1997, preliminary field assessment by cooperators indicates that there are significant classification errors, especially in the Cape Cod region. Although new GPS-logged aerial videography was obtained for Massachusetts as part of an NSF-funded project with the Department of Computer Science at the University of Massachusetts, there are no plans to redo the land cover map at this time.

Animal modeling: Predicted habitat maps are complete for birds, reptiles, and amphibians. With completion of the expert review of mammal range maps, the predicted habitats maps for mammals will be completed. Predicted habitat maps for all 273 vertebrates modeled in the Southern New England region will be finalized within the next six months.

Land stewardship mapping: All conservation lands in the region are mapped and classified according to conservation status. About 7% of the land area was classed in categories 1 & 2. However, this database will be updated prior to the final analyses planned within the next 12 months.

Analysis: Once the mammal habitat maps are completed and the land stewardship maps are updated, the species richness analyses will be redone and updated. The final gap analysis will be completed by December 2002.

Reporting and data distribution: Once the databases and analyses are updated, all data layers will be made available on a new home page in cooperation with UMass Extension. Until a new server is installed and the new home page developed, there will be only limited access to the data. We also plan to distribute the final report via CD-ROM. Availability of the data and final report is planned for December 2002.

Other accomplishments and innovations: A draft of a manual detailing the use of GPS-logged aerial videography for land cover mapping has been completed and is under revision.

Michigan

Under way

Anticipated completion date: January 2003

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Land cover: Land cover mapping follows the Upper Midwest GAP protocol at ftp://ftp.umesc.usgs.gov/pub/misc/umgap/98-g001.pdf. The Upper Peninsula and Northern Lower Peninsula are complete, and draft versions are available from the USGS Upper Midwest Environmental Sciences Center (UMESC). Mapping of the existing natural and seminatural land cover of southern Michigan continues. In cooperation with the DNR's Integrated Forest Monitoring Assessment and Prescription project (utilizing new Landsat 7 imagery), we began field work to develop revised land cover information for the Upper Peninsula and the Northern Lower Peninsula. A major effort to cross-walk the GAP classification to the NVCS is planned for 2002.

Animal modeling: Wildlife Division research faculty at Michigan State University will continue working with the Michigan Natural Features Inventory and other Wildlife Division staff on a species distribution modeling project. Most GAP program funding received from Upper Midwest GAP for fiscal year 2002 will be applied toward this work.

During fiscal year 2002, work will continue on the integration of existing species habitat databases into the GAP modeling process. Further refinement of the databases will occur with additional literature review. Initial distribution/occurrence models will be developed for most species.

Land stewardship mapping: The stewardship map has been delivered to UMESC and is being reviewed.

Reporting and data distribution: Draft land cover data and stewardship data are available from UMESC. Contact Daniel Fitzpatrick at (608) 781-6298 or Daniel_Fitzpatrick@usgs.gov.

Minnesota

Under way

Anticipated completion date: January 2003

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Land cover: Land cover mapping follows the Upper Midwest GAP protocol (ftp://ftp.umesc.usgs.gov/pub/misc/umgap/98-g001.pdf). The state DNR is finishing classification of the SW (mostly agricultural) quarter of the state. The following classification units are completed, and a draft version is available from the USGS Upper Midwest Environmental Sciences Center (UMESC): North Shore, Border Lakes East, Border Lakes West, North Tamarack Lowlands, South Tamarack Lowlands, East Chippewa Plains, West Chippewa Plains, Nashwauk Uplands, Laurentian Uplands, St. Louis Moraines, Pine Moraines and Outwash Plains, Mille Lacs Uplands, Agassiz Lowlands East, Agassiz Lowlands West, Anoka Sand Plain, Blufflands, and Oak Savannah and Rochester Plateau. A major effort to cross-walk the classification to the NVCS is planned for 2003.

Animal modeling: The ongoing state DNR vertebrate mapping effort will expand in 2002. Draft hexagon species range maps have been delivered to UMESC and are being reviewed. Species expert review teams are helping to develop habitat suitability. The animal modeling coordinator for the Minnesota DNR is Jodie Provost, Department of Natural Resources (Jodie.provost@dnr.state.mn.us).

Land stewardship mapping: Stewardship mapping is completed, and a draft version is available from UMESC. The Public Land Survey (PLS) was used as a base map. The section corners are located, and the 40-acre tracts are generated from an algorithm. Each 40-acre parcel is attributed for public landowner, manager, and stewardship status. The coverage is clipped and served in 1:100k mapquad tiles.

Reporting and data distribution: Draft land cover data and stewardship coverages are available from UMESC. Additional land cover data are expected to become available in 2002. Contact Daniel Fitzpatrick at (608) 781-6298 or Daniel_Fitzpatrick@usgs.gov.

Mississippi

Near completion

Anticipated completion date: December 2002

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Land cover: The MS-GAP land cover map was completed in 1999 and has been used by numerous state, federal, and local resource agencies. Over 100 individuals have requested these data for use in a wide variety of projects. The data will soon be downloadable from the MS-GAP home page and from the Mississippi Automated Research Information System (MARIS) Web site. MARIS is the GIS data clearinghouse for the state of Mississippi and can be found at http://www.maris.state.ms.us.

Animal modeling: Modeling of animal ranges and distribution has generally been completed. A few issues still persist on several herpetile species, but these issues will be resolved by late winter. Distributions have been developed for 402 species including 58 mammals, 216 birds, and 128 reptiles and amphibians. Reviews are complete on all models except the few herps.

Land stewardship mapping: Land stewardship mapping has been completed thanks to the aid of the Mississippi Department of Wildlife, Fisheries, and Parks and the U.S. Forest Service. As with most eastern states, Mississippi is comprised of mostly management status 4 lands. Less than 1% of the state is in status 1, and 7% of the state is in status 2.

Analysis: Analysis is mostly complete. The analysis section of the report is the final step to completion of this project. Once completed it will be sent to reviewers for comment.

Reporting and data distribution: The report is the current focus of MS-GAP. We have completed the land cover and stewardship sections and have sent them out for external review. The modeling is nearly complete. Analysis is the final section to complete.

Missouri

Near completion

Anticipated completion date: March 2002

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Land cover: Complete. Phase I land cover was completed by the Missouri Resource Assessment Partnership. Metadata has been compiled for the base land cover map as well as all derivative databases created from this base such as ecotones, interiors, etc. Ancillary land cover databases (sink holes, wetlands, glades, etc.) compiled for this project were also documented.

Animal modeling: Nearing completion. Three hundred forty-eight vertebrates were modeled (66 mammals, 164 birds, 74 reptiles, and 44 amphibians). Ninety-meter grids representing the species predicted distributions were created for final GAP reporting. Metadata is being compiled for these predictive species maps.

Land stewardship mapping: Complete. The stewardship layer was created by the Missouri Resource Assessment Partnership. Public lands comprise only 6.7% of Missouri with 4.7% under federal and 2% under state jurisdiction. All areas greater than 16 hectares were analyzed for biodiversity components. Metadata has been compiled for these stewardship maps.

Analysis: Complete. Upon review, another analysis was needed to meet national reporting guidelines. This analysis has been completed and added to the final report and deliverables for Missouri.

Reporting and data distribution: Nearing completion. The third draft of the final report will be mailed in December 2001. CDs are being assembled for distribution to the GAP Operations Office following the directory structures outlined for final reporting of data. Data distribution from these analyses will be posted on the Missouri Spatial Data Information Service (MSDIS) at http://msdis.missouri.edu. A link from this site will be created to the AMLs and programs written in support of this effort.

Montana

Complete (see http://www.wru.umt.edu/reports/gap/)

Nebraska

Under way (http://www.calmit.unl.edu/gap/)

Anticipated completion date: October 2002

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Land cover: The land cover map has been completed. We are finishing the accuracy assessment and preparing the metadata. Plans for the next twelve months include publishing the land cover map as an outreach product.

Animal modeling: We are in the midst of modeling vertebrate habitats using two approaches. First, a recursive partitioning program (QUEST) permits the rapid production and revision of classification and regression tree models to relate georeferenced occurrence data with environmental (land cover, climate, soils, terrain) variables (see article by Henebry et al. on page 22). Second, for those species lacking sufficient occurrence data to permit effective application of the recursive partitioning algorithm, we have turned to the "literature gestalt" method. Range maps are undergoing expert review. Accuracy assessments are being conducted with voucher specimens located in other museums and occurrence data from the literature. In 2002 we plan to complete habitat modeling and inversion to range maps, complete expert reviews and accuracy assessments, and prepare metadata.

Land stewardship mapping: Land stewardship mapping has been completed. We are now preparing the metadata.

Analysis: We are in the process of analyzing aspects of the stewardship and land cover maps with the vertebrate occurrence data used in the modeling and some of the reptile and amphibian draft models. Further analyses will be conducted as animal models are completed.

Reporting and data distribution: Metadata assembly, data lineage, and methods documentation are ongoing.

Aquatic GAP: We are collaborating with the Missouri Resource Assessment Partnership (MoRAP) to develop geospatial databases and implement Aquatic GAP in Nebraska. In order to provide a regionally consistent Aquatic GAP product, this effort will also involve close collaboration with Aquatic GAP programs in Iowa, Kansas, and South Dakota. Within Nebraska, Aquatic GAP will involve collaboration and cooperation with fisheries biologists, aquatic ecologists, and other scientists affiliated with the Nebraska Game and Parks Commission, the Nebraska Department of Natural Resources, the Nebraska Department of Environmental Quality, the University of Nebraska State Museum, The Nature Conservancy,

the University of Nebraska School of Natural Resource Sciences, the USDA National Agroforestry Center, and many additional university faculty, state and federal agencies, and private organizations.

GAP research: We are developing an approach to the regionalization of disparate land cover maps using image time series from coarse spatial but fine temporal resolution sensors, such as AVHRR and MODIS. The objective is to provide an integrated regional land cover map of the Great Plains that provides improved discrimination among grassland types and elimination of discordance of land cover classes across state boundaries.

Other accomplishments and innovations:

- Presentation of our approach to habitat modeling for reptile and amphibian species at

  (a) the U.S. Landscape Ecology Symposium in Tempe, AZ, April 25-30, 2001,

  (b) the Nebraska GIS/LIS Association meeting in Lincoln, NE, May 8-11, 2001,

  (c) the National Gap Analysis Program meeting in Brookings, SD, June 17-20, 2001, and

  (d) the Ecological Society of America meeting in Madison, WI, August 5-10, 2001.

  (e) the Nebraska State EPSCoR conference, Lincoln, NE, April 4-5, 2002.
- Presentation of our approach to habitat modeling for avian species at

  a) the Mid-America GIS Consortium meeting, Kansas City, MO, April 15-19, 2002,

  b) the U.S. Landscape Ecology Symposium in Lincoln, NE, April 23-28, 2002.
- Collaborating with Oak Ridge National Laboratory on objective ecoregionalizations of the data layers used for modeling wildlife-habitat relationships.
- Providing land cover data to the National Park Service for the Revised General Management Plan for the Niobrara National Scenic River.
- Continuation of work with regional partners in Great Plains GAP consortium.
- Working with Kansas toward comparing approaches to modeling species habitat and geographic ranges.
- Cooperating with Rainwater Basin Joint Venture (US Bureau of Reclamation–$180,000; NE Game and Parks Commission) in land cover mapping using 1997-98 TM data.
- Cooperation with a $50,000 project from the Nebraska Game and Parks Commission to enhance and update land cover maps for the Niobrara River watershed.
- Cooperating with the Nebraska Research Initiative in Geospatial Decision Systems.
- Participation in the Great Plains Cooperative Ecosystem Study Unit (CESU).
- Participation in a $100,000 NSF Biocomplexity Incubation Activity project on the ecology and geology of the Sandhills of Nebraska.
- Participation in a $1.2M grant from the U.S. Environmental Protection Agency for a three-year project to develop methods for lake classification in Nebraska.
- Participation in enhanced mapping of land cover for the Platte River watershed in Nebraska (including 1997–2000 change analysis) through Cooperative Hydrology Study (COHYST) consortium–$310,000.

Nevada

Update under way (see Southwest Regional GAP)

New Hampshire

(see Vermont and New Hampshire)

New Jersey

(see Maryland, Delaware, and New Jersey)

New Mexico

Update under way (see Southwest Regional GAP)

New York

Completed (see http://www.dnr.cornell.edu/gap/gap.htm)

North Carolina

Near completion

Anticipated completion date: June 2002

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Land cover: The statewide land cover map will be complete in the winter of 2002. In the spring an accuracy assessment based on ecological groups will assess the land cover using a stratified design with digital orthophoto quarter quads, aerial videography, and

field visits being used to label the assessment sites. A draft land cover has been mosaicked for the Roanoke-Tar-Neuse-Cape Fear Ecosystem for a collaborative project with the Fish and Wildlife Service.

Animal modeling: Preliminary models were run for the species occurring in the Roanoke-Tar-Neuse-Cape Fear Ecosystem in the fall of 2001. These models are being internally reviewed and revised and will be rerun when the statewide land cover becomes available in spring 2002. Additional ancillary data required to improve the predicted distributions are being compiled in the winter of 2001/02. The database of habitat relationships and ranges for each of the 414 species being modeled is complete.

Land stewardship mapping: This layer is complete. In developing this layer we have worked with a long list of cooperators including the NC Natural Heritage Program, the NC Center for Geographic Information and Analysis, NC Wildlife Resources Agency, NC Division of Coastal Management, Fish and Wildlife Service, and the NC Division of Parks and Recreation. The final coverage includes 395 managed areas that have been assigned a protection status of 1, 2, or 3. While we have been able to include many of the land trust lands with the help of our cooperators, we know land trust lands are underrepresented due to a lack of resources within the land trust offices to provide spatial representations of the lands they are protecting. The methods and metadata have been created and are ready for internal review. The final data layer and supporting documents will be available in spring 2002.

Analysis: Draft analyses have been completed for the Roanoke-Tar-Neuse-Cape Fear Ecosystem, which includes large portions of the Coastal Plain, Piedmont, and Sandhills of North Carolina. The analysis of the amount and distribution of statewide management lands has also been done. In the spring of 2002, analysis of the protected status of the terrestrial vertebrates and land cover types will be completed.

Reporting and data distribution: Data on the ranges of 414 terrestrial vertebrates and the land management status layer will be delivered via the NC-GAP Web site in the winter of 2002 (www.ncgap.ncsu.edu). The final report, land cover, and predicted distributions will be delivered via the Web following external review in spring 2002.

Other accomplishments and innovations: We will complete the work on the GAP Ecosystem Data Tool in the spring of 2002. This decision support tool was designed to help USFWS Refuges as well as Ecological Service offices address landscape conservation issues. For a more thorough description of the tool see "Taking Refuge-GAP a step further: The GAP Ecosystem Data Tool in the Roanoke-Tar-Neuse-Cape Fear Ecosystem" on page 29.

North Dakota

Under way

Anticipated completion date: March 2003

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Land cover: The analysis of plant species composition and biomass data from 3,468 range surveys on state school lands in North Dakota (ND) was the primary activity in 2001. Models predicting the relative abundance (% biomass) of common grass species in ND were created using Regression Tree Analysis. Environmental predictor variables included mean annual precipitation and temperature; percent sand, silt, and clay in the soil surface layer; root zone depth; and available water capacity. A plant community map was created from cluster analysis of the individual grass species' relative abundance maps. The plant community map was intersected with a land cover map produced from supervised cluster analysis and maximum likelihood classification of multitemporal Thematic Mapper imagery. The composite map provides information about the abundance of grass species and vegetation communities for the natural grassland class in the land cover map. A hierarchical vegetation community classification was developed from the range survey data set using two-way indicator species analysis (TWINSPAN). The TWINSPAN analysis included all plant species observed at the sample units, not just the common grass species used in the regression tree analysis. Results from these analyses will be interpreted in conjunction with the National Vegetation Classification System to develop the map classes and legend for the natural grassland component of the ND-GAP vegetation and land cover map. Primary activities in 2002 will be refinement of the regression tree and multitemporal Thematic Mapper imagery analyses, completion of a vegetation and land cover map for ND, and an accuracy assessment of the map.

Animal modeling: Range maps have been reviewed for the 289 breeding terrestrial vertebrate species included in ND-GAP. The development of wildlife habitat relationship (WHR) models in a Microsoft Access database in conjunction with Iowa and South Dakota GAP projects was almost completed. WHR models for all bird, amphibian, and reptile species have been reviewed. WHR models for all regional mammal species have been reviewed, and models for mammal species specific to North Dakota are in review. Efforts were made to identify additional reviewers for WHR models. A list of land cover types, ancillary layers, and ecotone layers necessary to run all WHR models was prepared. An SAS program was created that converts WHR information in the Access database to Excel spreadsheets for inspection by model reviewers and develops a script for use in ARC/INFO to execute the WHR models and produce species distribution maps. Efforts in 2002 will include the development of environmental data grids for modeling species distributions, the refinement of WHR models from reviewers' com-

ments, and production of species distribution maps.

Land stewardship mapping: Cooperators continued to provide significant in-kind resources with regard to public land stewardship maps. Draft vectors of U.S. Fish and Wildlife Service (FWS) fee-title lands and easement refuges were received. A draft vector of ND Game and Fish Department (NDGF) fee-title lands was received. The FWS and NDGF expect to complete their vectors in 2002. A vector of U.S. Forest Service Lands was received. The management intent of

some tracts may change, subject to the outcome of the final review and comment period for the Dakota Prairie Grasslands Management Plan. Efforts to assemble the individual public land ownership vectors into a single public land stewardship vector for ND were begun. Procedures for addressing edge-matching and polygon sliver problems, arising when vectors from different sources and scales are combined, were investigated. Procedures for categorizing biodiversity management status were modified for application to public lands in ND. The primary difficulty was reconciling the requirement for natural land cover with legislation and management objectives. Many public lands in ND have only fragments of natural land cover but have a biodiversity conservation objective. Strict adherence to the guidelines in the Mapping and Categorizing Land Stewardship Handbook would result in these lands being assigned a status 4, which is the lowest level. In 2002, we will complete the acquisition of vectors for individual public landowners and assemble and attribute a single public land stewardship vector for ND.

Other accomplishments and innovations: Strong, L., S. Magill, and D. Buhl . 2001. Integration of GIS and remote sensing for mapping land cover of the Northern Great Plains. 11th Annual National Gap Analysis Program Meeting, 12-20 June 2001, Brookings, SD.

Ohio

Under way

Anticipated completion date of terrestrial project: September 2004

Anticipated completion date of aquatic project: September 2003

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Land cover: Progress was made toward the goal of completing 30% of the land cover map by June 2002. Accelerated mapping activities began with the hiring of a vegetation classification specialist in May 2001 and increased participation in the project by the Ohio Department of Natural Resources (DNR) beginning in the summer of 2001. Methods and software for processing land cover images were successfully tested in a pilot project completed in September 2001. Digital aerial photography is being used in place of aerial videography as part of the accuracy assessment of the land cover map. Aerial photography was obtained from aircraft belonging to the Ohio DNR and Ohio Department of Transportation (ODOT). Landsat 7 scenes are being acquired from the OhioView program for dates as close as possible to those of the aerial photography and ground-truthing activities.

The effort to obtain digital aerial images and ground-truthed data will span late summer and fall 2001 and spring to fall 2002. In the fall of 2001 a total of 1,189 images were taken. Completing the aerial photography is estimated to require 41 days of flight time in 2002 to obtain 28,946 digital aerial images including overlap and side lap of TM scenes for Ohio and adjacent states. Ground-truthing was initiated in summer 2001 and will continue through the fall of 2002. Individual photos note the following characteristics: size, shape, pattern, and texture of tree species, tone of image, shadow cast, habitat and location, and association.

With grant support from the Ohio Lake Erie Protection Fund, 20 wetlands in the Ohio Lake Erie Basin were field-assessed during the summer of 2001 to provide ground-truth information on wetland plant alliances. Fieldwork and ground-truthing have shown that the aerial videography available from 1999 was not sufficiently detailed to map wetlands. The aerial photography being obtained for the land cover map will provide a greatly improved source of data. During the winter of 2001–02, aerial photos will be taken of wet woodlands. Aerial photos from leaf-off periods will be used in the interpretation of the location and extent of wooded wetlands that are often not discernable from dry woodlands during the leaf-on period.

Animal modeling: The OH-GAP Project consists of terrestrial and aquatic components.

Terrestrial vertebrate species: Hexagon range maps were released for review in spring of 2001, and the expert review of these maps was completed in the fall of 2001 for all amphibians, birds, and mammals. The expert review of reptiles is still under way; further comments on range information are expected from two herpetologists. The reptile range maps will be 75% complete in June 2002 and fully completed in 2003.

The literature review of habitat affinity information for each terrestrial vertebrate species is being developed and is connected to an Access database. The Vertebrate Modeling Database developed by Kansas GAP was used as a guide. This work has been ongoing since 2000. The literature review of terrestrial vertebrates is complete for 50% of the species. The habitat affinity database and literature review are planned for completion in 2003.

Aquatic species: The Ohio Aquatic GAP Project is closely following the Missouri Aquatic GAP protocol and methods. This method uses the valley-segment classification of stream reaches statewide and relates the occurrence of fish species to valley-segment type(s).

The Ohio Aquatic GAP Project was about 50% completed in 2001. Distribution maps of fish species were completed in July 2001 and released on the OH-GAP Web page for expert review. These data include maps of 160 native and introduced fish species that reproduce in Ohio streams. Corrections based on expert reviews will be finalized in January 2002. The fish species data were compiled from published and unpublished records of the Ohio Environmental Protection Agency, ODOT, Ohio DNR, and U.S. Geological Survey. According to Ohio DNR, the 4,525 data points in the Ohio fish database represent the fish species occurrence in about 50% of the 43,000 named streams in Ohio. Fish distribution maps will be finalized and published on the OH-GAP Web page and on CD in spring 2002.

In 2002, fish species modeling will be undertaken using two approaches: simple overlays of species occurrence on valley-segment types and a statistical modeling approach. Either the GARP model (Stockwell and Peterson 1999) or the WhyWhere model (Stockwell 2001) will be selected. A journal article discussing the research findings for fish species of the Ohio Aquatic GAP Project is planned for 2002 and would be submitted for publication in early 2003.

Land stewardship mapping: The land stewardship map was 25% complete by the end of 2001 and includes Ohio's state and federal lands. In 2002, county and regional parks, natural areas, and privately owned preserves will be added, where available, for Ohio's 88 counties. Land stewardship categories and status codes are being inventoried and developed as the data are received. Completion of the land stewardship map is planned for May 2003.

Analysis: The accuracy of simple overlays relating fish species occurrence to valley segment types will be compared to the accuracy of statistical models to determine the most effective and efficient method to analyze the aquatic data. The statistical models are the GARP model and the WhyWhere model. These are expert systems that test the fit of several types of statistical and nonstatistical models for spatial data analysis. The GARP model was successfully pilot tested on a small Ohio watershed for the Ohio Aquatic GAP Project in 2000. The WhyWhere model is relatively new and has not yet been published but is reported by the author to be superior to GARP.

Reporting and data distribution: A factsheet on the OH-GAP Project was published and released in October 2001 and included a description of the terrestrial, aquatic, and wetland components. A CD of the Ohio Aquatic GAP data will be published by June 2002. The data will describe Ohio valley-segment types and the Ohio fish database.

Other accomplishments and innovations: New techniques for accuracy assessment of the land cover map were used by the OH-GAP Project in cooperation with the Ohio DNR, Division of Wildlife (DOW). The DOW purchased a digital camera (Nikon D1X), GPS unit, laptop computer, and software to obtain digital aerial images of Ohio vegetation. In the early fall of 2001, a total of 1,189 images were taken in areas represented by two different Landsat 7 TM scenes. The images are of very high quality with a resolution of 3,008 pixels at a photo scale of 1:40,000 and offer a ground resolution better than 1 meter. Each aerial photo covers 0.479 km^2.

In 2002, the OH-GAP Project plans to work with federal, state, and local stakeholders in Cuyahoga and Summit Counties, Ohio, to develop a Decision Support System to integrate watershed and transportation planning in the watershed of the Cuyahoga River. The stakeholders represent the environmental and transportation agencies in northeastern Ohio. The OH-GAP Project will provide the biodiversity data for this project.

Literature cited:

Stockwell, D., and D. Peterson. 1999. The GARP modeling system: Problems and solutions to automated spatial prediction. *Int. J. Geographical Information Science* 13:143-158.

Stockwell, D. 2001. WhyWhere. Accessed December 1, 2001, at URL http://biodi.sdsc.edu/ww_home.html.

Oklahoma

Complete

Contact: William L. Fisher
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Land cover: The land cover map of Oklahoma is complete. The map contains 39 land cover types ranging from oak-pine forest in southeastern Oklahoma to eastern redcedar-oak woodland in central Oklahoma to grama-buffalograss prairie in the western Oklahoma panhandle. The accuracy of the map was assessed.

Animal modeling: Wildlife habitat relation models were run for 402 terrestrial vertebrate species, including 50 amphibians, 81 reptiles, 178 birds, and 93 mammals. All maps of modeled species were reviewed by state experts and revised. The accuracy of the maps was assessed.

Land stewardship mapping: The land stewardship map is complete. Over 94% of the land in Oklahoma is in private ownership. Status 1 lands comprise only 0.2% and status 2 lands 1.7% of the area of Oklahoma. (See article on page 6.)

Analysis: Analyses indicate that because of the small percentage of status 1 and 2 lands in Oklahoma, few vegetation and animal species elements are actively managed for biodiversity conservation.

Reporting and data distribution: The draft final report has been peer-reviewed. The Oklahoma Cooperative Fish and Wildlife Research Unit and Oklahoma State University will be handling initial distribution of the OK-GAP final report and data.

Oregon

Complete
(see http://www.natureserve.org/nhp/us/or/index.htm#whats)

Pennsylvania

Complete (see http://www.orser.psu.edu/PAGAP/gappage.html)

Rhode Island

(see Massachusetts, Connecticut, & Rhode Island)

South Carolina

Complete

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Land cover: Land cover mapping is complete. The final detailed land cover was modeled from an initial generalized land cover and ancillary data. The 27-class land cover used in the vertebrate modeling was derived from the final 54-class land cover. The ancillary data sources included detailed county-level soil maps, National Wetlands Inventory coverages, and elevational data in the Blue Ridge Province. Accuracy assessment was completed using a combination of aerial videography, ground assessment, and Digital Ortho Quarter Quads. Accuracy of the land cover at classifications corresponding to Anderson Level I and II were 71.9% and 51.4%, respectively.

Animal modeling: Animal modeling is complete for 455 vertebrate species. Accuracy assessment was conducted using species lists from five sites throughout the state. Overall species richness was highest in the deciduous forests comprising bottomland hardwoods in the coastal plain and deciduous forests of the mountains and upper piedmont. Accuracy of the vertebrate predicted distributions was determined through comparison with sites possessing a list of species. Accuracy ranged from 57% to 85.5%, depending on comparison data.

Land stewardship mapping: Land stewardship mapping is completed. Overall, various state, federal, and private landowners protect 6580 sq. km or 8.1% of South Carolina habitat in all GAP status categories.

Analysis: A gap analysis was conducted, indicating varying levels of protection for vertebrate species in South Carolina. Protection for species of concern varies depending on knowledge of habitat requirements and the type of habitat in which the species occurs. Species with well-known and specific habitat requirements tended to receive greater protection than many other species.

Reporting and data distribution: The SC-GAP report is expected to be distributed within the year along with the standard data sets. In addition, the South Carolina GIS Clearinghouse will begin making data available early in 2002. The GIS Clearinghouse is maintained by SCDNR Natural Resources Information and Analysis Section and can be found at http://water.dnr.state.sc.us/gisdata/.

Other accomplishments and innovations: SC-GAP has been involved in a statewide inventory of ant species that will be completed by early 2003. In conjunction with the ant survey, other invertebrates have been inventoried, and those data will be incorporated if appropriate.

South Dakota

Near completion

Anticipated completion date: May 2002

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Vickie J. Smith, Coordinator
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Land cover: Completed in spring 2000. No new work has been done. Accuracy assessment of the Black Hills is planned.

Animal modeling: Habitat models have been completed for all 362 species and are currently under expert review. After reviews are completed, models will be finalized.

Land stewardship: Completed in summer 2000. No new work has been done.

Aquatic GAP: Range maps and habitat models have been completed for 112 fish species. Expert review is currently under way.

Analysis: In addition to land cover and 11-digit hydrologic unit analyses completed in 2000, gap analysis was completed for simplified valley-segment codes (5 of 10 attributes–temperature, stream size, flow, gradient, and groundwater potential–were evaluated as concatenated valley-segment codes). Most (154) valley-segment types are protected in less than 10% of their range, including 34 rare types with less than 10 reaches or less than 100 meters long. Two codes (20101 and 20103) were represented in at least 10% of stewardship status 1 or 2 lands. One code (24110) was represented in greater than 20% of status 1 and 2 lands, but less than 50% of its range. This was a rare type only represented by five reaches. Two codes (23110 and 24120) were protected in 100% of their ranges. Both were rare types with less than 10 reaches represented.

Reporting and data distribution: The final report is currently 50% complete; reporting of analysis of vertebrate and aquatic modeling

is under way. Metadata and final attributing per GAP standards is being completed for all coverages.

Southwest Regional GAP (SWReGAP)

Update under way for the five-state region encompassing Arizona, Colorado, Nevada, New Mexico, and Utah. State coordination for all aspects of the project is facilitated through the SWReGAP Web site (http://leopold.nmsu.edu/fwscoop/swregap/default.htm).

Anticipated completion date: December 2004

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RS/GIS Laboratory
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Land cover: The RS/GIS Lab at Utah State University is acting as the regional land cover mapping lab for the five-state southwest region. Coordination with the other four states is facilitated through a Web page that allows access to spatial data, procedural documents, and an Internet Map Server (http://www.gis.usu.edu/docs/projects/swgap). During 2001 the RS/GIS Lab completed the following tasks for the five-state region:

- Coordinated with EROS Data Center (EDC) on imagery acquisition - A tracking system was developed to monitor scene acquisition for approximately 80 ETM scenes for spring, summer, and fall dates (~240 scenes total). At present, approximately 90% of all ETM scenes have been received from EDC and have been distributed among the five participating states. The RS/GIS Lab at USU keeps copies of all ETM imagery, and a second copy is kept by the participating agency for each state.
- Developed a methodology for image standardization - All imagery received from EDC has been terrain-corrected, but has not been radiometrically corrected. USU has adopted a COST (Cosine Theta) atmospheric standardization procedure for image standardization. To facilitate the use of this procedure for image standardization, USU developed a program that can be used to "read-in" information from the scene's header file and, with limited input from a technician, create an ERDAS Imagine model (.gmd) that can be used to perform the COST correction.
- Developed a DEM-derived landform model - One of the most promising avenues by which a higher level of classification accuracy and community definition will be achieved, is to improve the modeling of biophysical parameters that predict potential vegetation. To this end, USU has developed a DEM-derived landform model that can be generated using an ArcInfo AML. The model provides 10 basic landform classes and can be refined further by incorporating life zones using a vegetation index or elevation grid.
- Developed image processing and classification procedures - Land cover classification methods have traditionally been based on somewhat subjective methods of analysis. USU has been developing a land cover classification methodology that incorporates Classification and Regression Tree (CART) tools. As part of developing this protocol, USU hosted a regional workshop (Jan. 3–4, 2002) to train participating state land cover analysts using this approach.

Land cover activities for 2001 have focused on (1) initiating and maintaining a cooperative network of agencies, organizations, and individuals; (2) final selection, acquisition, and selected preprocessing of satellite imagery; (3) collection of vegetation data at analytical training sites; (4) collection and organization of ancillary data; (5) review of the National Vegetation Classification System (NVCS); and (6) hiring of land cover staff.

Imagery selection, acquisition, and preprocessing - SWReGAP is using Landsat 7 Thematic Mapper imagery from 1999–2001. Final selection of satellite imagery was completed during 2001, and the list was submitted to EDC through the regional land cover lab at USU. This was facilitated through the Regional Coordinator and in coordination with adjacent states for concurrence on imagery.

Imagery began arriving to states in summer 2001, and delivery is expected to be complete in January 2002. The New Mexico lab is assisting with regional land cover mapping by preprocessing of selected imagery for New Mexico and Arizona.

Collection of vegetation data - A field data collection workshop was held in May 24–25, 2001, for states participating in the SWReGAP project. This workshop was sponsored by the regional land cover mapping lab and was hosted by Nevada project staff. The purpose was to standardize field collection protocols regionwide.

Training sites continue to be obtained through both fieldwork and cooperative interaction in order to get an initial representation of all National Vegetation Classification System (NVCS) alliances in the project area. In the southwest states, existing training sites have been obtained from a variety of sources such as the Colorado Vegetation Classification Project (CDOW Basinwide Inventory) led by the Colorado Division of Wildlife and the Bureau of Land Management (BLM); military installations in New Mexico (Fort Bliss Military Reservation and White Sands Missile Range); and New Mexico Natural Heritage Program.

Current field training site data continue to be collected by project personnel throughout the mapping zones assigned to states. Some examples of field data collection efforts in New Mexico and Colorado include the following. The New Mexico project has visited 1,904 sites among the 17 mapping zones assigned to the project. Within these mapping zones, data collection represents 87 of the approximately 155 alliances. New Mexico is using these data, available satellite imagery, and known alliances to target specific alliances within each mapping zone for additional sampling. In Colorado, the Southern Piedmont (298 field sites), High Plains (215 field sites), Northern Piedmont (106 field sites), and North Mountain Parks (44 field sites) mapping zones have been the focus of field collection efforts. In spring 2002 additional field crews will be deployed for regionwide work where more sampling is needed to improve the accuracy of vegetation type predictions.

Collection of ancillary data - Ancillary data have been obtained from a variety of sources across the five-state region. Example sources include the BLM, Earth Data Analysis Center at the University of New Mexico, U.S. Geological Survey, and military installations such as White Sands Missile Range. These ancillary data include GIS coverages (e.g., urban and agriculture coverages) and remotely sensed data (i.e., digital orthophoto quads, NALC triplicates, etc.).

Classification system - The NVCS is being employed to develop classification consistency across the five-state area. Keith Schulz with NatureServe works with the southwest states to ensure SWReGAP land cover types are regionally consistent and linked directly to NVCS alliances. During the course of 2001 Keith has provided periodic alliance updates for the region and by state. In addition he has participated in various land cover mapping workshops and coordinated with field crews such as Colorado to address their plant identification questions.

The southwest states, in turn, work with NatureServe to refine their alliance-level classification as needed and continue to review the NVCS as training site data are obtained. Data to potentially describe new alliances are sent to Keith Schulz by individual states. For example, the NVCS is being expanded for Arizona by adding alliances already described in other states but not attributed to Arizona and describing new alliances to Arizona and the NVCS. The Arizona project is providing the field data and initial analysis necessary to get these provisional alliances and "new" alliances into the NVCS.

NatureServe has developed an Access database to manage the state land cover type information by mapping zone as southwest states work together to develop cover types that can be consistently applied across the southwestern region. This database will also be used to manage information on new alliances that are developed over the course of this project.

Animal habitat modeling: The New Mexico Cooperative Fish and Wildlife Research Unit (NMCFWRU) in Las Cruces is acting as the regional animal habitat modeling lab for the five-state southwest region. During 2001 the New Mexico lab has focused on identifying the list of animal taxa for habitat modeling and orchestrating review of this list among the five projects.

The New Mexico lab submitted, for regional review, a packet on taxa inclusion and the preliminary assignment of species to each project in May 2001. There were 866 species-level taxa included in the review package, as well as a written Decision Rule for Taxa Inclusion, Exclusion, and Modeling Allocation. The objective of this packet was to provide specific, consistent criteria to select the candidate taxa across the five-state region and build consensus on allocation of species for modeling. Responses from states indicated interest in shifting allocation of modeling responsibility for 57 taxa. At end of year, reconciliation of taxa inclusion and project responsibilities was still ongoing.

Efforts also were under way to complete consistent taxa naming and coding by cross-referencing Integrated Taxonomic Information System (ITIS) and NatureServe (former TNC) conventions. Lee O'Brien, Colorado Project Coordinator, has provided taxonomic/animal modeling expertise in facilitating cross-walking between SWReGAP and reference material from ITIS.

In preparation for animal habitat modeling, the New Mexico project has identified the 8-digit HUC (watershed codes) as the coverage to be used in range delineation. Once the taxa list has been reviewed with regional consensus, the methodology and coverage will be sent to respective states for this range delineation.

Land stewardship mapping: Land stewardship mapping is expected to begin in the spring of 2003. States are completing various preliminary tasks in preparation. Arizona is focusing on obtaining current information on tribal lands. New Mexico has reviewed the existing Public Land Survey System layer for New Mexico. Both Colorado and New Mexico propose to bring personnel on board during summer and fall 2002 to assist further with land stewardship mapping activities. Currently the region is con-

sidering collaboration with the BLM on obtaining regionwide stewardship information.

Regional cooperation: Regional cooperation continues to be critical to the proper functioning of SWReGAP. Individual states contributed to the regional project during 2001 by participating in (1) a field data collection workshop in May, hosted by NV-GAP with planning by UT-GAP; (2) regional breakout sessions held at the National Gap Analysis Meeting to coordinate animal habitat modeling and land cover mapping activities; (3) preparation of a cooperative poster for the region; (4) assistance to the SWReGAP coordinator in presenting SWReGAP to federal agencies; and (5) regional Web site and listserv.

Field data collection workshop - The objectives of the field data collection workshop were to arrive at a consensus on the field data collection protocols that would act as the standard among the five participating states. This was accomplished through both in-field meetings and group discussion. Issues that were discussed included minimum data requirements, field sampling methods, and sample data stratification.

Regional poster and presentations - Through a coordinated effort with the Regional Coordinator and other projects, the New Mexico project produced an information poster to be displayed and used throughout the region. The poster is entitled "Southwest Regional Gap Analysis Project: Enhancing Your Conservation Options Beyond Political Boundaries" and is available for use by all southwest states through the SWReGAP Web site. The Colorado project assisted the SWReGAP coordinator in scheduling and making presentations to the Region 2 Forest Service office and the Region 8 Environmental Protection Agency office in Denver.

Regional Web site and listserv - The New Mexico Project has created and maintained the main Web page and listserv communications for the entire region. Although extensive modification is currently occurring, the basic functioning service has been provided. In the near future, this Web site will include an interactive GIS application (ARCIMS) and other data serving functions.

Analysis: Analysis for SWReGAP will take place when the mapping tasks are completed.

Reporting and data distribution: All products derived from SWReGAP are scheduled to be complete by 2004 with some possibility of timeline revisions to be considered by the group in 2002.

Other accomplishments and innovations:

AZ-GAP: As tribal lands cover more than 25% of Arizona, conducting fieldwork in all areas of the state necessitated proactive communication with Native American tribes to gain their support in conducting fieldwork on tribal lands. A special effort has been made to work with the larger tribes to get them involved in the project at the very beginning. Involvement at this stage and throughout the project creates better products by incorporating indigenous knowledge and provides more support for the project and more appropriate use of the products.

The Arizona project produced a paper that highlights how the new project in Arizona will build and improve upon the previous one. The citation is:

Jacobs, S.R., K.A. Thomas, and C.A. Drost. 2001. Mapping land cover and animal species distributions for conservation planning: An overview of the Southwest Regional Gap Analysis Program in Arizona. In van Riper, C., III, K. Thomas, and M. Stuart, editors. Proceedings of the Fifth Biennial Conference of Research on the Colorado Plateau. U.S. Geological Survey/FRESC Report Series USGSFRESC/COPL/2001/24.

CO-GAP: The Colorado project conducted a prototype evaluation of helicopter-based inventory, patterned after inventory methodologies utilized by the BLM in Alaska and California (see article on page 19). Though this method seems expensive, the ability to get to remote sites, view them synoptically in a manner similar to satellite view angles, and the efficiency of between-site travel needs to be evaluated relative to the cost of ground-based inventory work. Background information on use of airborne platforms for collection of ancillary ground reference/truthing information was presented to the SWReGAP group during the National GAP Conference. Colorado has posted their imagery information to a Web page for the benefit of other SWReGAP project personnel.

NM-GAP: A presentation about perceptions of NM-GAP data use from government and tribal planners in New Mexico was made at the National Gap Analysis meeting in June 2001. Dr. Russell Winn from New Mexico State University presented work done as a follow-up to the original New Mexico Gap Analysis Project. His presentation was entitled "Analysis of stimuli and barriers to use of NM-GAP data by county, tribal, and regional planners." This presentation was co-authored by Diane-Michele Prindeville and Bruce C. Thompson (see article on page 32).

Tennessee

Complete

Contact: Jeanette Jones
Tennessee Wildlife Resources Agency, Nashville
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Land cover: Completed. The final map contains 30 land cover classes with 18 forest alliance groups.

Animal modeling: Predicted species distributions and species richness data have been completed for Tennessee's 364 terrestrial vertebrate species.

Land stewardship mapping: Completed.

Analysis: Gap analysis has been completed.

Reporting and data distribution: Revisions to the final report are in progress.

Texas

Near completion

Anticipated completion date: April 2002

Contact: Nick C. Parker
Texas Cooperative Fish and Wildlife Research Unit
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Land cover: The final map contains 38 land cover classes.

Animal modeling: Predicted species distribution and species richness data have been completed for the 665 terrestrial vertebrates in Texas.

Land stewardship mapping: Completed.

Analysis: Gap analysis has been completed.

Reporting and data distribution: The first draft of the final report is near completion. Last September, the Nimba virus caused major damage in our system, requiring time and resources to recover data, replace some equipment, and get TX-GAP back on track. The report and all data are being prepared for distribution on the Web at http://apollo1.tcru.ttu.edu/.

Other accomplishments and innovations: On-the-ground photographs collected from the field are now being placed on the Web at http://apollo1.tcru.ttu.edu/. The photographs are arranged in a database searchable by keyword, location, and other identifiers. This system has been developed to archive photos collected around the world.

Data from TX-GAP were combined with other data sets to produce a report titled "Texas Parks and Wildlife for the 21st Century." The 20-volume report has been summarized into a 48-page full-color document titled "Texas Parks and Wildlife for the 21st Century: An overview of the Texas Tech University studies in conservation and recreation for the coming decades." The complete report and summary are available at http://apollo1.tcru.ttu.edu/. This report has been distributed statewide and is being used by state legislators, the public, educators, and Texas Parks and Wildlife to guide natural resource programs over the next three decades.

Utah

Update under way (see Southwest Regional GAP)

Vermont and New Hampshire

Near completion

Anticipated completion date: January 2002

Contact: David E. Capen
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Land cover: Complete.

Animal modeling: Complete.

Land stewardship mapping: Complete.

Analysis: Nearly complete.

Reporting and data distribution: Digital coverages were submitted in mid-2001. The final report will be distributed for peer review in early 2002.

Virginia

Complete (see http://fwie.fw.vt.edu/WWW/vagap/)

Washington

Complete (see http://www.wa.gov/wdfw/wlm/gap/dataprod.htm)

West Virginia

Complete (see final report summary on page 47)

Wisconsin

Under way

Anticipated completion date: January 2003

Contact: Daniel Fitzpatrick
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Land cover: Land cover mapping follows the Upper Midwest GAP protocol (ftp://ftp.umesc.usgs.gov/pub/misc/umgap/98-g001.pdf). Land cover mapping is completed, and a draft version is available from the USGS Upper Midwest Environmental Sciences Center (UMESC). A major effort to cross-walk the classification to the NVCS is planned for 2002.

Animal modeling: Wisconsin vertebrate mapping will be undertaken by UMESC. A regional vertebrate mapping approach, coor-

dinated by UMESC, was initiated in the fall of 2000. Regional species lists, range maps based on EPA hexagons, and habitat suitability matrices stratified by Bailey's Ecoregion Provinces are a few of the strategies being employed to minimize cross-state edge-matching and to reduce duplication of efforts.

Land stewardship mapping: The Wisconsin DNR has completed compiling data on state, county, and U.S. Forest Service lands. UMESC is acquiring coverages of DOI lands and compiling the complete stewardship coverage.

Reporting and data distribution: Land cover data are available from UMESC. Contact Daniel Fitzpatrick at (608) 781-6298 or Daniel_Fitzpatrick@usgs.gov.

Wyoming

Complete (see http://sdvc.uwyo.edu/wbn/gap.html)

NOTES AND ANNOUNCEMENTS

ESA Releases New Standards

The Ecological Society of America's Vegetation Classification Panel has released "Standards for Associations and Alliances of the U.S. National Vegetation Classification: Version 1" (see http://vegbank.nceas.ucsb.edu/vegbank/panel/standards.html). Culminating a seven-year process, the purpose of this document is to provide both a technical and a general basis for describing and classifying the plant associations and alliances that are to be formally recognized as units of vegetation under the U.S. National Vegetation Classification (NVC). The standards presented are recommendations for anybody proposing additions, deletions, or other changes to the named floristic-level units of the NVC. The document begins with the rationale for developing the standards and a review of the history and development of vegetation classification in the United States. The detailed standards for establishing and revising the floristic units of vegetation include:

- definitions of the association and alliance concepts;
- requirements for vegetation field plots data acquisition;
- classification and description of associations and alliances;
- peer review of vegetation types proposed for inclusion in the NVC;
- a structure for data access and management (see www.vegbank.org).

The document concludes with a discussion of future prospects and new directions in vegetation classification. These standards are written with the intention that they will be revised, and new versions of the document will be produced as needed.

Michael Jennings
National Gap Analysis Program, Moscow, Idaho

Announcing National GAP Annual Meeting in West Virginia

The 12th Annual National Gap Analysis Program Meeting will be held July 31 - August 4, 2002. This year's meeting location is the U.S. Fish and Wildlife Service's National Conservation Training Center in Shepherdstown, West Virginia. The meeting is hosted by the West Virginia Gap Analysis Project and USGS/BRD.

This meeting should be attended by those actively working on Gap Analysis projects and their cooperators as well as potential users of GAP data, such as state and federal agencies, developers, planners, conservation groups, and others involved in management of natural resources. Sessions will focus on

- land cover,
- aquatic GAP,
- applications and socioeconomics,
- animal modeling, and
- accuracy assessment.

Additional information on the meeting can be found at http://www.gap.uidaho.edu/Meetings/2002/default.htm or by contacting Elisabeth Brackney at (208) 885-3560 or brackney@uidaho.edu.

Elisabeth Brackney
National Gap Analysis Program, Moscow, Idaho

New Movie to Explain GAP

In an effort to make the Gap Analysis Program more accessible to those who are not familiar with GIS applications and who do not have a scientific background, we have developed a short Flash-style movie about the program. This movie, "Gap Analysis: Keeping Common Species Common" is designed to be a tool that can be used to explain GAP to the general public, the environmental community, and others who could benefit from GAP data. The movie will be available soon at http://www.gap.uidaho.edu/flash/gapmovie.htm.

Jill Maxwell
National Gap Analysis Program, Moscow, Idaho

The Gap Analysis Bulletin is published annually by the USGS Biological Resources Division's Gap Analysis Program. The editors for this issue are Elisabeth S. Brackney, Michael D. Jennings, Kevin J. Gergely, and Ree Brannon. To receive the bulletin, write to: Gap Analysis Bulletin, USGS/BRD/Gap Analysis Program, 530 S. Asbury Street, Suite 1, Moscow, ID 83843, fax: (208) 885-3618, e-mail: brackney@uidaho.edu. A digital version of the Bulletin, containing additional graphics, is available on the Internet at http://www.gap.uidaho.edu/gap/Bulletins/10/index.htm

Suggested citation: Brackney, E.S., M.D. Jennings, K.J. Gergely, and R. Brannon, editors. 2001. Gap Analysis Bulletin No. 10. USGS/BRD/Gap Analysis Program, Moscow, Idaho.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
December 2001

3. REPORT TYPE AND DATES COVERED
Information Report

4. TITLE AND SUBTITLE
Gap Analysis Bulletin

5. FUNDING NUMBERS

6. AUTHOR(S)
Elisabeth S. Brackney, Michael D. Jennings, Kevin J. Gergely, and Ree Brannon, editors

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
USGS/BRD/Gap Analysis Program
530 S. Asbury St., Suite 1
Moscow, ID 83843

8. PERFORMING ORGANIZATION REPORT NUMBER
No. 10

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Geological Survey
Biological Resources Discipline
Reston, VA 20192

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Published annually

12a. DISTRIBUTION AVAILABILITY STATEMENT
Approved for public release; distribution unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
The 2001 issue of the Gap Analysis Bulletin is the tenth in a series of annual publications produced by the National Gap Analysis Program. Gap Analysis Bulletin No. 10 features 13 articles on various aspects of gap analysis methods and results. Topics addressed include land cover mapping, animal distribution modeling, and applications. The bulletin also includes a section on the current status of each GAP state project. This issue also contains summaries of two final reports from recently completed GAP state projects.

14. SUBJECT TERMS
Biodiversity, conservation biology, Gap Analysis Program, land cover, land use planning, remote sensing, vegetation classification, vegetation mapping

15. NUMBER OF PAGES
69

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	SAR

TABLE OF CONTENTS CONTINUED

Presorted Standard
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